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Nature of resistance to diplodia stalk rot of corn

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NATURE OF RESISTANCE TO DIPLODIA STALK ROT OF CORN

by

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INTRODUCTION

The nature of resistance to stalk rot of corn is not understood although a number of modifying factors involved have been reported. Since stalk rot resistance is an important quality desired in corn, a better understanding of the nature of resistance might enable plant breeders to more easily secure this character in varieties used for commercial production. Furthermore, cultural and fertility practices based on this knowledge may be devised that would lead to reduction in severity of the disease and render useful varieties which are deficient in resistance but otherwise agronomically suitable.

Since Diplodia zeae (Schw.) Lev. has been used extensively in this region for measuring resistance to natural stalk rotting, this organism was selected for use in this study. The purpose of the study was to gain a better understanding of the factors involved in resistance to spread of the pathogen as measured by tissue discoloration in stalks of corn following inoculation.

Although a number of factors such as reserve food, structural constituents, and low moisture content of stalk tissue had been associated with resistance, only one fact was clear, resistance in plants of nearly all varieties tended to decrease as they neared maturity. It seemed likely that the seasonal trend of one of these factors might be correlated to

some degree with resistance or susceptibility. The initial objective in this work, therefore, was to examine seasonal trends in composition of stalks of varieties showing a wide range of stalk rot resistance. It was hoped that these results would provide a clue to guide subsequent work on the nature of the resistance mechanism.

REVIEW OF LITERATURE

Diplodia zeae (Schw.) Lev. is in the Fungi Imperfecti, order Sphaeropsidales and family Sphaerioidaceae. Stalk rot caused by Diplodia zeae rarely occurs before the ears have reached the dough stage and is not exhibited by most lines of corn prior to pollination. Infection of lower internodes usually results in a rotting and brown discoloration of the internode with discoloration of tissue usually extending into adjoining internodes in severe rotting. The symptoms of stalk rot are premature dying of the plant, chaffy ears, weak shanks, dropped ears, and leaning and fallen plants. Ears from fallen plants are likely to be of poor quality and usually become rotted following contact with moist soil. Black pycnidia of the pathogen may appear on all above-ground lesions or within the infected stalk, developing most abundantly late in the fall or early spring. On ears, the white to gray mycelium appears between the kernels and grows into the husk, cementing it to the kernels. Pycnidia may form at the base or on the sides of kernels, on the cob, and on the husks. In seedling infections, brown cortical lesions are visible on the internode between the scutellum and the coleoptile, and seminal roots are often destroyed (25).

General Pathology of Diplodia Stalk Rot of Corn

Diplodia zeae was first reported as a parasite of corn by Heald, Wilcox, and Pool (15) in 1909. They reported the infection as a localized ear rot disease. The presence of fruiting bodies of this organism on the stalks was regarded as a result of saprophytic growth. Burrill and Barrett (3) reported a slight growth of the fungus following artificial inoculation of the stalks, but they regarded infection of stalks in the field only as a disease of senility.

Melhus and Durrell (39) reported that Diplodia zeae attacked all parts of the plant, grew internally, and came to the surface to sporulate. Durrell (10) believed that moisture was the determining factor in the growth reaction of the fungus and that the amount of August rainfall determined the extent of disease. To produce an epidemic, high August precipitation must be accompanied by a maximum of stored food, cessation of growth, and the loosening of the leaf sheaths. Although D. zeae entered ears through the silks, Durrell believed the sequence of events in stalk infection to be: (a) cessation of stalk elongation and the loosening of the sheaths after flowering, (b) accumulation of pollen, spores, and moisture behind the leaf sheaths, (c) germination of spores and the utilization of pollen and possibly exuded sugars as substrate, (d) attack of thin walled sheath cells

causing reddish or purplish spots and blotches on the upper leaf sheath, and (e) penetration of outer cells of the node and growth into the stalk tissue, growth downward being more rapid than upward possibly due to more moisture in the lower stalk. A large percentage of the ear infection occurred by the growth of the fungus up the ear shank from the infected nodes. Ears could also be infected by the fungus penetrating through the base of the husk. He concluded from the field data that: (a) D. zeae attacked chiefly the lower two or three nodes and rarely infected the sixth or seventh node, (b) the first node was not as frequently infected as the second node, (c) little relation existed between Diplodia infections on the stalk, shank, and ear, and (d) stalks still alive and growing were less subject to Diplodia attack than those which were on the decline. Durrell reported that D. zeae grew well on a number of standard media, cornmeal, oatmeal, and bean stems. Using synthetic media, he found that the fungus grew well on sucrose, dextrose, maltose, and lactose but made slowest growth on the latter. Pure cellulose agar induced profuse growth and sporulation. Durrell stated: "The utilization of cellulose by the fungus is of particular interest as the penetration and growth in the stalk and the weakening of the nodes is thus more readily understood." Soil experiments suggested that D. zeae could survive in a purely saprophytic manner and emphasized its ability to survive in the soil.

According to McNew (38), initial infection by Diplodia occurs from the soil or the seed, and it then invades the mesocotyl or the crown of the young plant. These young plants survive if adventitious roots form. They remain parasitized during continued growth with fungal spread limited until sometime after pollination. When the plant matures, a decrease in physiological activity leads to active invasion of the lower internodes of the stalk. McKeen (37) believed that stalk rot followed a rotting of one or more of the roots; the stalk rot organisms then passed through the crown and spread rapidly to the stalk.

Roberts (43) recently reported that infection of D. zeae progressed similarly regardless of the date of inoculation except that progress within the stalk was somewhat slower after the later dates of inoculation. Working with the second above ground internode, he reported that in two weeks the internode was necrotic and a discoloration had occurred around the inside of the rind and margin of nodal tissue. D. zeae was isolated from all necrotic tissue of the inoculated internode and from most necrotic bundles therein. Water soaked nodal tissue surrounding the discoloration was always sterile. Many discolored vascular tissue samples from the internode above the inoculation point were sterile. In all instances where discoloration of pith cells was observed, the intercellular spaces were filled with a dark colored substance. Necrosis within the bundle was often more intense

in phloem than in xylem, the sheath being slightly discolored. Discoloration in the vascular tissue appeared in advance of the mycelia. In infected areas, sieve tubes in the phloem and vessels in the xylem were plugged with dark brown substances which gave the appearance of a mass of fungal hyphae. Hyphae found in phloem appeared smaller than those found in pith cells or xylem elements. D. zeae was isolated at later stages from necrotic bundles but not pith tissue in the third internode above the inoculation point. Some bundles were discolored above this internode but were sterile. He concluded that spread of the fungus in the parenchyma tissue was primarily intercellular at first, later permeating the cells. Passage through the node was restricted except through bundles or necrotic tissue. Lignified cells did not prevent penetration by D. zeae but merely slowed down this process.

Hooker (21) found that varieties varied in degree of resistance or susceptibility to basal stalk rot but that all lines were relatively susceptible to Diplodia in the internodes below the ear. In the varieties used, no resistance in one plant part was positively associated with resistance in another plant part, but there were individual varieties with good resistance to the same organism in several plant parts. He explained low association between seedling blight resistance and stalk rot resistance by variation in maturity dates. Late maturing varieties were more resistant to stalk rot than those maturing earlier. Limited observations

indicated that most plants naturally infected with stalk rotting pathogens were invaded from the base of the stalk and that these plants nearly always had badly diseased root systems.

An artificial inoculation technique for determination of resistance to stalk rots was developed by Smith, Hoppe, and Holbert (50). The authors reported a comparison of the incidence of stalk rot caused by Diplodia under natural and artificial inoculation. The correlation between natural infection and broken stalks was 0.909 and between natural infection and cortical or pith spread after inoculation, 0.853 and 0.878, respectively.

Hooker (22) also reported that the most rapid spread of discoloration occurred during the early part of the inoculation period. In susceptible varieties, the rate of spread was rapid in the first two weeks after inoculation. In varieties of intermediate resistance, the rate of spread was fairly constant during the four week interval following inoculation. In resistant varieties, no spread occurred after the first week following inoculation. When all inbred varieties studied were considered, the time from silking to inoculation had little effect on the rate with which the disease developed in the stalks during the four weeks following inoculation. The data indicated that regardless of the extent to which the fungus invaded the basal internodes, progressively more spread could be expected if inoculations

were performed in successive internodes up the stalk; the fifth internode of the varieties studied was equally susceptible. It was suggested that similar internodes should be inoculated to measure comparative resistance to stalk rot among corn plants or varieties. Inoculation of the first or second elongated internode above the ground between one and three weeks after silking was recommended as most satisfactory for this purpose with stalk rot ratings preferably made four weeks after inoculation.

Carbohydrate Reserve as a Factor in Stalk Rot Resistance and Susceptibility

Holbert, et al. (20) reported that stalk tissue of partially defoliated plants was infected earlier and to a much greater extent by D. zeae following natural and artificial infection than non-defoliated plants. Prior to maturity, feeding of second brood cinch bugs on the lower plant parts caused a marked increase in stalk tissue invasion by the fungus. Stalks, shanks, and ears, exposed to natural and artificial chilling and freezing temperatures, were invaded to a much greater extent by D. zeae as these tissues approached maturity than were the same tissues of comparable plants not so exposed. They stated, "In each case, increased susceptibility of stalks to the fungus is associated with conditions that may well result in a reduction of the carbo-

hydrate reserve of the plant." This did not hold true for susceptibility in the ears".

DeTurk, et al. (8) reported that the greater the percentage of total sugars in the corn stalks, the less was the stalk injury caused by D. zeae or by low temperatures. Reducing leaf area by 30 per cent lowered sugar content in the stalks of the lines tested and increased susceptibility of the plants to both D. zeae and cold injury. A similar leaf pruning ten days before pollination caused the greatest reduction in total sugars in the lower one-third of the stalk and the least reduction in the shank. The decrease in sugars was confined to the sucrose fraction, reducing sugars remaining unaffected. Although stalk injury by cold or D. zeae varied among the plants tested, a tendency for increased injury to follow lowered sugar content was noted.

Durrell (11) reported that resistant varieties contained more liquified tissue, particularly in the lower nodes, than susceptible varieties. Smith, et al. (50) suggested that the difference in the relative amounts of sclerenchyma tissue and in the thickness of the cell walls in the parenchyma tissue of corn varieties may explain differences in ability to restrict the advance of fungi in the stalk. Johann and Dickson (24) reported that stalks which were collected during vegetative growth and dried contained an ether soluble substance which retarded growth of D. zeae in culture. Certain varieties retained more of the growth retarding substance

throughout the period of maturation than did others. This correlates with the general trend of susceptibility of stalks during this period. Artificial defoliation or prevention of pollination did not modify the growth-retarding effects of ether extracts of plants so treated. Furthermore, a growth retarding substance also was present in expressed stalk juice, and it retarded growth of D. zeae in culture as did the ether extracts. The growth-retarding substance was stable to heat and somewhat soluble in water. Taylor (51) reported that the ability of the stalk juice to support growth of D. zeae was inversely related to stalk rot resistance, but he concluded that the resistance to Diplodia stalk rot in the varieties examined did not result from a direct nutritional effect on the fungus. Davis, et al. (7) found that hot water extracts of dried pith contained a substance which modified the growth of Diplodia in culture. The authors stated, "Apparently these properties of the mature cornstalk upon which growth and perhaps resistance or susceptibility to Diplodia stalk rot are dependent may be removed by hot water." Extracts from eight of the ten varieties studied were analyzed for reducing sugars, total sugars, sucrose, and total nitrogen to determine if growth of the organism in culture could be correlated with any of the more simple reserves or residues present in the mature cornstalk. No correlation was found between growth and total solubles, growth and reducing sugars, and growth and total sugars. No ranking of field response to disease

and growth of the organism in culture was presented.

Relation between Soil Fertility and Stalk Rot

The literature on the relationship between plant nutrition and development of stalk rot in corn is very limited. In general, the balance of nitrogen and potassium seems to play a role in the development of stalk rot and, consequently, in the lodging of plants. Koehler, et al. (30) found that lime applications did not influence stalk breakage but did reduce root lodging.

Hoffer and Carr (16) reported that iron and other metallic bases can accumulate in organic combinations in internal tissue of nodes where the fibrovascular bundles branch to form the bundles extending into the roots, leaves, and husks of the ears. Accumulation occurs first in the phloem cells and later in the walls and lumina of the xylem elements. The amounts accumulated seemed to be directly related to the premature dying of the lowest leaves. Malnutrition and root rot symptoms were frequently associated with discolored nodal tissue. Iron compounds were present in larger quantities, as determined by chemical analysis, and oxidase and catalase activities were greater in the nodes of infected stalks than in those of normal healthy stalks of the same age in the same soil. Aluminum and manganese compounds also were found in greater quantities. The pH of this tissue

was 6.2-6.8 in stalks showing disease symptoms of root rots and pH 4.0-5.2 in normal stalks, the latter being approximately that of the internodal tissue.

Hoffer and Carr (17) tested the effects of added iron salts on nodal tissue and found that many iron salts, especially ferrous sulfate, increased catalase and oxidase action and caused the nodal tissue to become brown and disintegrated. These conditions in healthy stalks were similar to those of infected stalks. Aluminum salts also stimulated catalase and oxidase action while copper sulfate in a 0.01 N solution was very toxic and the nodes were destroyed. Check plants supplied with water or with nutritive salt solution showed no harmful effects from the treatment.

Hoffer and Trost (19) reported that the accumulation of iron and aluminum compounds in the nodal tissues of corn plants was affected by soil condition as well as the genetic composition of the strain of corn. The selective capacity for accumulation of aluminum was associated with retarded growth and the increased susceptibility to root rot. In plants grown on potassium-supplied soil either as potassium alone or in combination with other treatments, the accumulation of iron was slight. The process by which potash prevented these accumulations was not known. The best treatment was a combination of nitrate and potash applied regardless of the concentration of limestone applied. The absorption of aluminum by the plants and its distribution was not

affected by any of the soil treatments, but the quantities in the plants were very low. Hoffer and Carr (18) stated,

> At times, the rot diseases may be very severe, but the damage caused by them seems to be influenced by certain soil conditions which are associated with deficiencies of the essential nutrients or with unbalanced combinations of available salts for absorption by the plants. Frequently the extent of damage may vary markedly in certain parts of fields or in different fields wherein the same seed stock had been planted.

High organic matter and low calcium and phosphorus soils seemed to be the best environment for the development of seedling blight. Later in the season abundant root rots and nodal discoloration developed in such areas. Sweetcorn grown in clover sod (pH 5.6) was stunted in August, contained high concentration of metals in nodal tissues, and rotted severely at maturity. Sweet corn grown in soil previously cropped in corn (pH 6.2) showed good growth and was less attacked.

The status of the work of Hoffer as regards to root rots and stalk rots can be better ascertained in light of more recent work if the effect of potassium and the nitrate-potassium treatment on metal accumulation and susceptibility is noted. The accumulation of nutrients in plants has been studied by Loehwing (34). He reported that sap of corn, oats, and wheat is more acid in high potash soil than in high lime soil and that the soil and sap acidity favor iron solubility and absorption. The potassium treatments resulted in stiff and erect stems and well developed lignified tissues. Rogers and Shive (44) reported that the pH of various tissues of corn

were as follows: xylem parenchyma, pH 4.8-4.6; xylem vessels, pH 4.4-4.0; bundle sheath, pH 4.6-4.4; sclerenchma pH 4.8-4.5; phloem, pH 6.2-5.8; cortex, pH 6.0-5.6; and leaf mesophyll, pH 6.0-5.6. The plants showed very heavy accumulation of iron, primarily in the bundle sheaths and cortical cells immediately surrounding it. Small amounts of iron were always found in the vessels of both the stalk and leaves but none in cortical cells of stalks or mesophyll cells of the leaf slightly removed from the bundle region. No trace of iron was found in the phloem of the stem or leaf. However, large accumulations of iron were observed in the phloem of prop roots. The authors concluded that chlorosis in the presence of high amounts of iron in vascular tissue was due to the steep pH gradient between cells of the bundle sheath and those immediately to the exterior and that in the corn plant, resistance to movement of iron may become rather serious under slightly unfavorable growth conditions. It appears, therefore, from these studies, that the work of Hoffer and others (18, 19, 16) and its relation to stalk or root rot may be explained on the basis of potassium effects on pH gradients in the plant. The accumulation of these materials, therefore, may be a result of some other physiological process more closely related to resistance to disease.

Koehler (29) stated that high nitrate levels and an out of balance fertility with regard to potash can cause serious stalk rots. Lang and Bauer (32) found a great variation

among corn hybrids with respect to potassium utilization. In a study of two hybrids on potassium-deficient and potassium-supplied soil, they found that both hybrids lodged badly when grown on potassium-deficient soil and that on potassium-supplied soil one hybrid continued to lodge but the other showed little lodging. Krantz and Chandler (31) found that additional application of potash fertilizer to soil with sufficient potassium to cause no deficiency symptoms did not affect yield or lodging. When potash was applied to soils on which plants showed deficiency symptoms, lodging and stalk breakage was decreased and yield was increased. Increasing nitrogen increased yield but had no effect on lodging.

Otto and Everett (41) reported that in general the severity of stalk rot increased with increased applications of nitrogen and decreased with an increased supply of potassium. They concluded that from their study, it appeared, that the greatest promise for control of stalk rot lies in the use of resistant hybrids on soils where the nitrogen supply is not exceedingly high in relation to potassium supply.

Foley and Wernham (12) reported that application of nitrogen alone greatly increased the severity of internodal rot, stalk breakage, and premature dying but that application of potassium alone had the opposite effect. When the nitrogen and potassium level was high, the addition of phosphorus had no effect on development of internal rot and the amount of stalk breakage, but it did increase the amount of premature

dying.

Woods and Rossman (58) reported that stalk lodging increased about four times with population increases from 10,300 to 22,900 plants per acre but that picker losses did not increase proportionately indicating that the mechanical harvesters were recovering a large portion of the ears of broken plants.

Composition of Corn Stalk

Schweitzer (48) analyzed corn at 14 successive stages of growth and found that for the whole plant the fiber percentage increased rapidly at the beginning of growth then remained constant for a month and finally decreased after fertilization had occurred. Considering the stalk alone, the crude fiber increased constantly, dry weight became constant following fertilization, and ether extractable material, proteins, and carbohydrates, decreased at maturity. Jones and Huston (27) analyzed corn at eight different stages of development and found that dry matter, crude fiber, fat, and nitrogen free extracts remained constant in the stalks after formation of ears while the nitrogen fraction in the stalks constantly decreased. Ince (23) analyzed corn at eight different stages of growth and found that the stalk constantly decreased in percentage of proteins. Peterson (42) found that mature cornstalks consisted primarily of 24 per cent

lignin, 27 per cent pentosan, 36 per cent cellulose. Little polyhexose material subject to acid hydrolysis and no pectic material could be identified. The outer shell of the stalk, the pith parenchyma and the inner vascular bundle were analyzed separately. The outer shell and central vascular bundles were predominantly fibrous in structure and of woody appearance. The pith parenchyma consisted of more or less cubical cells of soft and spongy texture. The analysis of these tissues showed approximately the same percentage chemical composition as the total stalk. This fact was surprising for it had been presumed that most of the lignin content of corn-stalks would be found in the vascular bundles and outer rind, and the hemicellulose would be largely concentrated in the parenchymatous tissue. Bair (1) reported that accumulation of dry matter in corn plants tended to follow a sigmoid curve. Accumulation was slow following seedling emergence, rapid until the end of the first 40-50 days, uniform in the next 40-50 days, and dropped off rapidly as maturity was approached.

Miller (40) reported that during the first week following emergence, leaves accounted for almost 100 per cent of the dry matter of the plant. During the second week, the stalk increased in dry weight. Between the eighth and ninth week the stem and the leaves comprised an equal portion of the total dry weight. In the next five weeks, the stalk increased in dry weight to a greater extent than did the leaves. The ear reached its maximum dry weight at the end of the fourteenth

week while husks reached the maximum at the end of the thirteenth week. As the plant approached maturity, leaves accounted for 20.5 per cent, stalks 34 per cent, and ear 32 per cent of the total dry weight.

Sayre (45) found the maximum rate of dry matter accumulation occurred between July 26 and August 4. This period included tasseling, silking, and cessation of increase in height. Jordan, et al. (28) observed that dry matter accumulation approached linearity under high nitrogen fertilization. Barr (2) using the internode section of stalk taken from the first internode above the ear found that the diurnal fluctuations were highest in the day, peaking in the afternoon, and lowest at 4 A.M. The major fluctuation of carbohydrates occurred in the leaves and stalks and was confined largely to the invert sugar fraction.

Sayre, et al. (47) analyzed the stalk of control and bagged plants at intervals of ten days and reported that preventing the fruiting of corn resulted in a gradual accumulation of total sugars in the stalk while in control plants the maximum content occurred on September 11 and decreased toward maturity. Barrenness by drought resulted in a similar accumulation of total sugars as in bagging treatments. Changes in the total sugar content were due to changes in the sucrose fraction and not to free reducing sugars. Loomis (35) found that sucrose increased nearly 100 per cent in defruited stalks. He (35) also reported that barren plants had 37 per

cent of the stalk weights and 19 per cent of the total weight of normal plants. The moisture percentages of barren and normal plants were comparable. The carbohydrate accumulation above the normal level resulting from drought injury was equally distributed between dextrin and sucrose with other fractions increasing only slightly. Rotting stalks were very low in reducing sugars and sucrose, with losses of dry weight up to 25 per cent. The per cent acid hydrolyzable carbohydrates increased probably due to the fact that this fraction is more resistant than sucrose to destruction by microorganisms. The accumulation of nitrates in drought injured stalks was striking. The percentage of total protein nitrogen also increased in the drought-injured plants. Conrad (4) reported that sugars, in the hybrid studied, decreased from levels as high as 18 per cent at the blossom stage down to amounts below 2.5 per cent at maturity, while plants without seed-bearing ears at maturity were consistantly higher in both roots and stalks than those plants with seed-bearing ears. This was especially true in regard to stalks. Van Reen and Singleton (56) found that the first internodes above the uppermost brace roots of five inbred varieties of corn analyzed at the late whorl stage had less than 0.2 per cent sucrose and 2 per cent total sugars. Sucrose content of ear-bearing plants of inbred C 103 reached a peak of 12 per cent sucrose about three weeks after pollination, while bagged plants averaged 15 per cent sucrose. Varieties Wf, Tl, and Hy

reached their peak sucrose content at the same time but were lower in percentage sucrose, 9 per cent, 6 per cent, and 4 per cent, respectively. While C 103 continued to maintain a high sucrose content after peaking, these three varieties decreased. Variety 38-11 followed a pattern similar to C 103, peaking at 5 per cent sucrose content three weeks after pollination and retaining this level for a longer period than the other varieties. No great differences were noted between plants with or without ears until three or more weeks after pollination at which time the stalks without ears were higher in sucrose content and maintained their high content for a longer period than ear-producing stalks. There was a gradual but small increase in Brix readings for all inbreds from the first internode sample to the ear internode with no significant increase in internodes above this point. Grain developed by C 103 compared favorably with grain developed by the other inbreds at the third and fifth week after pollination and with all inbreds except Wf at the seventh week after pollination, Wf having 23 per cent more shelled grain than C 103. It was concluded that Wf, Tl, Hy, and 38-11 had all the sucrose in the plant translocated to the ear. While ear development had a marked influence on sucrose content in the stalk, it was not possible to explain the difference among varieties on the basis of ear development alone.

Sayre and Morris (46), using a modification of the Quesumberg-Thomas method of sugar analysis, reported that

sugars could be extracted by sap expression from corn blades, sheaths, or stalk tissue with little or no error in excess of that to be expected from duplicate samples extracted using the conventional 80 per cent ethanol extraction method. Hassid (13, 14) described a ceric sulfate method for the determination of reducing sugar and sucrose content in plant material. This method has been widely used and generally accepted.

Lennox, et al. (33) in a study on the application of the hand refractometer in sugarcane analysis, reported a high degree of correlation between Brix refractive index and the sucrose as determined by chemical methods. The authors concluded that Brix readings could be used with assurance as a measure of sucrose content where great accuracy is not required or possible to attain. Van Reen and Singleton (56) reported a good correlation between Brix readings and sucrose content of stalk juice of five corn inbreds. They stated that Brix readings may not be reliable estimates of sucrose concentrations in all inbreds since some may store more of their total sugars as hexose rather than as sucrose, or the concentration of salts and other non-sugar components may vary.

MATERIALS AND METHODS

Field and Laboratory Procedures - 1954

Field procedures

Six inbred varieties of corn were used in this experiment: B2, B14, Wf9, 38-11, Oh41, and OS420. The field experiment consisted of three replications, five plots per replicate, one row of each variety randomized in each plot, and 13 plants per row planted 1 foot apart. Border rows were planted on each end of the experimental area and side borders were provided by adjacent experiments. All seeds were treated with Arasan and planted May 12, 1954. Diseased or severely retarded plants were eliminated whenever observed throughout the season.

For each variety, two of the five plots per replicate were selected at random for defruiting treatment. Defruiting was accomplished when 50 per cent of the ears of the variety in the replicate had silked, silking being defined as the stage at which approximately 1 inch of silks were exposed. New ears forming on defruited plants were removed at weekly intervals.

Each variety was sampled eight times at approximately weekly intervals after silking beginning July 28, 1954. Field samples consisted of the first and second elongated internodes

above the uppermost brace roots. These were obtained by cutting the stalk below the node with brace roots and through the third elongated internode above the brace roots. These samples were obtained from the field before sunrise of the sample date to avoid any changes in carbohydrate composition (3). One sample was taken at random from each row in the plots at each sample date. The maximum number of stalks sampled per variety per replicate was five, three normal and two defruited. Samples were tagged, collected in plastic bags, and immersed in chipped ice until placed under refrigeration. The time from beginning of sampling to refrigeration varied between a period of 1 and 1.5 hours.

A Diplodia zeae spore suspension was used to inoculate plants for stalk rot ratings. Stalk rot ratings were obtained from plants inoculated August 13 and rated September 13, 1954. Stalk rot ratings of normal plants were obtained from an adjacent experiment conducted by Dr. A. L. Hooker. Stalk rot ratings of defruited plants inoculated August 13 and rated September 18 were obtained from the experiment described, using all defruited plants in excess of those required for stalk samples. In inoculation, the center of the first elongated internode above the uppermost brace roots was punctured by a hollow steel inoculating needle and the spore suspension was gravity injected into the pith. This method is the same as that used by Hooker (21), which was developed by Smith, et al. (50).

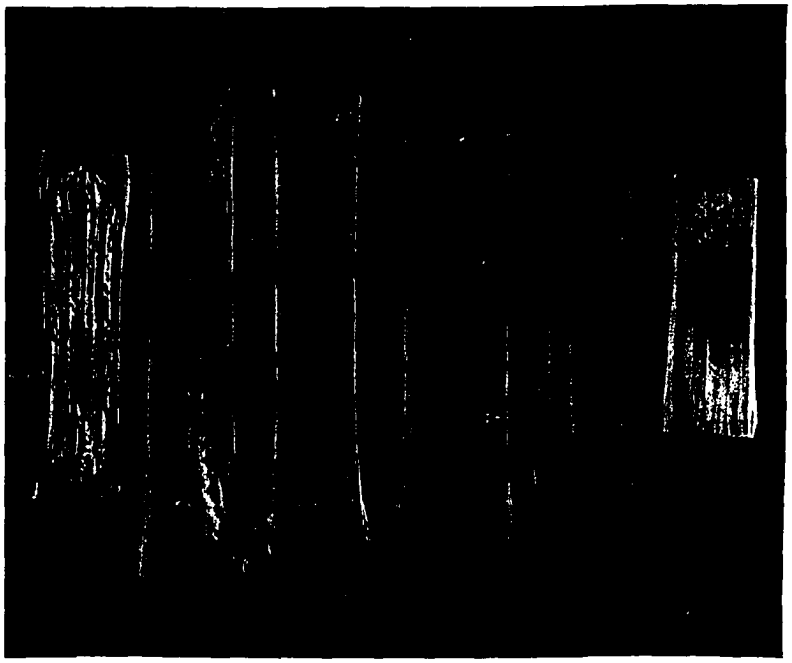
Inoculated stalks were rated using the discoloration resulting from inoculation as the basis for comparison of plant response. The stalks were split lengthwise with a knife, and the area of internodal discoloration recorded for each plant according to a stalk discoloration scale of 1 to 6, 1 being the most resistant and 6 the most susceptible. The area discolored was considered to represent the area infected by the inoculated or accompanying organisms. The rating scale is as follows:

1. Up to 25 per cent of the inoculated internode discolored.
2. 26 to 50 per cent of the inoculated internode discolored.
3. 51 to 75 per cent of the inoculated internode discolored.
4. 75 to 100 per cent of the inoculated internode discolored.
5. 100 per cent of the inoculated internode and the nodal and internodal tissue of adjacent internode discolored.
6. As 5 above with the plant dead.

Figure 1 shows typical stalk discoloration following inoculation in resistant to susceptible varieties. Hooker (22) showed that stalk to stalk variability within varieties was small and on the basis of previous experience, an average of ten plants was considered adequate for obtaining replicate averages. This photograph also points out the difficulty which occasionally occurs in estimating the extent of dis-

Figure 1. Typical stalk discoloration in first internodes above the uppermost brace rootsof resistant and susceptible varieties inoculated August 25 and rated September 22, 1955. The stalk rot ratings from right to left are 1, 1, 2, 3, 4, and 4.

Figure 2. Typical pith condition of the first through sixth internodes above the uppermost brace roots of variety B14 on September 22, 1955. The pith condition rating for the six internodes beginning with the first internode, on the right, are 1, 2, 3, 4, 4, and 4.



coloration. There is some variation in individual judgement in estimating areas. However, a given individual experienced in rating the area of discoloration can make these estimations with good uniformity.

Although only applicable to 1955 and 1956 studies, the pith condition ratings are given at this point for comparison with discoloration ratings. Figure 2 shows typical pith condition for first through sixth internodes above the uppermost brace roots of variety B14. The extent of spongy or fluffy dry pith is substituted for the extent of discoloration. Since spread of the organism through nodal tissue was not studied, only the internodal pith tissue was rated and these pith condition ratings are, therefore, limited to 4.

Laboratory procedure

Field samples were rearranged and grouped according to the field replications. The replications were processed in the same sequence at each sampling date, and samples were processed at random from the replication group. For each sample, Brix readings were obtained from the second internode pith juice, and physical measurements of the first internode and its subdivisions were recorded.

Brix readings. The second internode was removed from the sample, split lengthwise, and a small piece of pith removed from the center of the internode with a cork borer 1.2 cm. in diameter. The pith piece was placed in a hand press

obtained from a Zeiss hand refractometer kit and the expressed juice collected. The refractive index (Brix reading) of the expressed juice was determined with a Bausch and Lomb hand refractometer, calibrated in per cent total dissolved solids.

Physical measurements of the first elongated internode and its subdivision. The first internode was removed from the sample excluding all nodal tissue, weighed, and the average of two perpendicular diameter measurements and two opposite side length measurements recorded, and then it was split lengthwise into approximately equal pieces. One piece was reweighed and split into smaller pieces which were placed in a beaker and dried at 100° C. for 60 to 72 hours and reweighed. The remaining piece was split into very thin pieces and placed in a labelled jar. Approximately 150 ml. of hot 80 per cent ethanol was then added to the jar which was sealed and placed in storage.

Sugar determination method. Slices preserved in ethanol were washed with 80 per cent ethanol and the washings collected in the jar. The washed slices then were cut into pieces 1 cm. or less in length, ground for 4 minutes in 125 to 150 ml. of 80 per cent ethanol using a Servall Omni-Mixer, and the extract filtered through paper on a 9 cm. Buchner funnel. The rotor assembly, container, and ground fiber residue then were washed with 80 per cent ethanol. The washings and filtrate were transferred back to the jar. The ethanol extract was diluted to 500 ml. and completely mixed.

A 50 ml. aliquot was withdrawn and concentrated on a water bath until all of the alcohol had evaporated. The sample was diluted with distilled water and cooled to room temperature. One ml. of saturated neutral lead acetate was added to the beaker and the mixture was stirred using a rubber policeman. The sample was quickly filtered into a 125 ml. Erlenmeyer flask containing 10 ml. of dipotassium phosphate solution, 125 g. per liter. The residue was washed with distilled water. The lead phosphate precipitate was filtered off and washed and the filtrate collected in a 100 ml. volumetric flask and diluted to volume. A 50 ml. aliquot was then transferred to a 125 ml. Erlenmeyer flask for sucrose hydrolysis. One drop of 20 per cent acetic acid and three drops of an invertase solution were added to the aliquot. Before analysis, three drops of a 4N sodium hydroxide solution were added to make the solution alkaline. Aliquots of the original and the hydrolyzed sugar solution were analyzed by the ceric sulfate method described by Hassid (13, 14).

Seven extracted sample residues, which had been collected in the process of preparing samples for sugar determination, were selected at random and extracted with 80 per cent ethanol for 36 hours using a soxhlet extraction apparatus. The soxhlet extract was collected and sugar determined as previously described enabling the estimation of efficiency of sugar extraction by the grinding method. The results of

these seven analyses indicated that more than 97 per cent of the reducing sugars and, in all cases except one, about 100 per cent of the sucrose was removed from the sample by the grinding method. The exception for sucrose was 93 per cent extracted from a sample containing a very low amount of sucrose. The grinding method was considered satisfactory for this study and replaced the usual soxhlet procedure for extraction

Field and Laboratory Procedure - 1955

Field procedure

The six inbred varieties studied in 1954 were used in a three replicate experiment in 1955. The varieties were randomized as five row plots within each replicate with 24 plants 1 foot apart per row. Border rows were planted on all sides of the experimental area. All seeds were treated with Arasan and planted May 17, 1955. Diseased or severely retarded plants were eliminated whenever observed throughout the season. All plants were sprayed to minimize corn borer damage at the appropriate times.

Within each five row plot, one row was inoculated August 15, one row was inoculated August 25, and the remaining three rows were used for plant samples for laboratory studies. Ten plants of one of these three rows were inoculated September

30. All excess plants in these rows then were used to determine natural rotting of crowns and stalks on October 11.

Inoculations were performed August 15 by insertion of a Diplodia infected oat kernel into a hand drilled hole in the first elongated internode above the brace roots. The holes were plugged with cotton. Stalks inoculated on this date were rated for stalk rot on September 13 and October 11 at the rate of ten stalks per date. Pith condition also was rated on these dates. These pith condition ratings were based on the same scale as pith discoloration ratings. The extent of dry, spongy or crumbling type parenchyma was substituted for stalk discoloration in this rating technique. These observations were made on upper internodes adjacent to the internode inoculated. Since no method was available to predict the ability of the organisms in stalks to spread through nodal tissue, the pith condition ratings were limited to one internode and, therefore, to a maximum rating of 4. Figure 2 shows a range of typical pith condition ratings of 1 to 4 in first through sixth internodes of variety B14.

Inoculations were performed on August 25 with a Diplodia spore suspension as in 1954. The first ten plants in the row were inoculated in the first elongated internode above the uppermost brace root and the remaining plants in the fourth internode. These plants were rated for stalk rot and pith condition on September 22. Pith condition ratings were based on observations on upper internodes adjacent to the internode

inoculated. Ten plants of one of the three remaining rows of each variety in each replicate were inoculated, using the infected oat kernel method previously described, on September 30 and were rated on October 11.

Field samples, taken from the three uninoculated rows at the rate of one plant per row per sample date, consisted of the first and second internodes above the uppermost brace roots as in 1954. Sample dates were July 26, August 2, 9, 16, 23, and 30, September 14 and October 4. Only the first internode was used in this study. Samples were obtained before sunrise, tagged, collected in plastic bags, removed from the field, and placed under refrigeration. The time from beginning of sampling to refrigeration was less than one hour.

Laboratory procedure

Field samples were rearranged and grouped according to the three field replications. The replications were processed in the same sequence at each sampling date and samples were randomly processed from the replication group. For each sample, Brix readings were obtained from the first internode pith juice, and physical measurements of the first internode and its subdivisions were recorded.

Brix readings. The first internode was removed from the sample excluding all nodal tissue. After removing a longitudinal pith core by means of cork bore 1.2 cm. in diameter,

the outer internodal piece was split lengthwise and a small piece of remaining pith was removed using the same cork borer. The small pith piece was placed in a hand press, the expressed juice collected and refractive index determined using a Bausch and Lomb hand refractometer. When the outer portion of the internode was investigated, the residue of the small piece removed for sap expression was returned to the sample to be included in the dry weight determination.

Physical measurements of the first elongated internode and its subdivisions. The first internode was removed from the sample, excluding all nodal tissue, and on August 2 and 23, September 14, and October 4, the fresh weight and volume determined by water displacement were recorded. On all sample dates, a longitudinal pith core was removed by means of a cork borer 1.2 cm. in diameter. Length and fresh weights of these pith cores were recorded. The outer part of the internode then was split and Brix reading recorded.

Dry weights were obtained after drying the intact pith cores and lengthwise sliced outer piece for 48 to 60 hours at 100° C.

Field and Laboratory Procedures - 1956

Field procedure

Twenty varieties of corn were used in a four replicate experiment: B2, B14, Wf9, 38-11, Oh41, OS420, Ia153, M14,

W22R, 187-2, R101, B37, W17RB, Oh29, Wf9 x B14, Wf9 x 38-11, Wf9 x M14, B14 x Oh41, B14 x OS420, and C131 x B14. Each replicate consisted of 20 plots, five rows of one variety per plot, and 13 plants per row planted 1 foot apart. Border rows were planted on each side of the experimental area. All seeds were treated with Arasan and planted on May 9, 1956.

Within each five row plot, one row was inoculated in the first elongated internode above the brace root, one row was inoculated in the fourth internode, and the remaining three rows were used for obtaining plant samples for laboratory studies. Ten of the excess plants in the three uninoculated rows were used to obtain pith condition ratings of the first and fourth internodes. All inoculations were made on August 7 and stalk rot and pith ratings were recorded on September 7.

Field samples, taken from the three uninoculated rows at the rate of one plant per row per sample date, consisted of the first through fourth elongated internodes above the uppermost brace roots on August 1 and September 7 and the first and second internodes on July 18, August 15, and August 31. Because of the large number of samples involved, two replicates were collected and processed in each of two successive days, the last date being recorded as the sample date. Field samples were obtained beginning before 7 A.M., collected in premarked paper bags, removed from the field and placed under refrigeration. The time from beginning of sampling to

refrigeration varied between two and three hours.

Laboratory procedure

Field samples were rearranged and grouped according to the field replications. The replications were processed in the same sequence at each sample date. Samples were processed at random from the replication group. Pith cores were withdrawn from the first internode on all sample dates and from the fourth internode on August 1 and September 7 as in 1955. The length and fresh weight of the pith core was recorded and each core cut into discs approximately 2 mm. thick, placed in small jars containing boiling 80 per cent ethanol, boiled ten minutes, cooled, capped, and placed in storage.

Parenchyma tissue was examined for the purpose of determining the nature of the spongy dry pith and the position of the mycelium in relation to discoloration and spongy dry pith by using a neutral red stain and plasmolytic solutions. This vital stain technique described by Tribe (52) enabled the determination of living cells by means of red staining and plasmolytic response of living protoplasts. Pieces of tissue cut free hand or with a sliding microtome were placed in a solution composed of 8.5 ml. of 1 M sucrose, mannitol, or KNO_3, 1.0 ml. of 1.0 per cent neutral red stain, and a few drops of phosphate buffer, pH 7.6. After ten to 20 minutes, the pieces were examined microscopically.

EXPERIMENTAL RESULTS

Experimental Results - 1954

The six inbred varieties of corn investigated in this year were selected for study on the basis of previous knowledge of their responses to inoculation with D. zeae and general field performance. The purpose of this year's work was to seek information which would suggest a promising attack on mechanisms of resistance. Since resistance decreased following pollination, the seasonal development of the host after this time was chosen as the period of study. The relationship of carbohydrate changes with time to stalk rot ratings was considered to be of primary importance. However, in order to obtain a greater amount of information, this study was coupled with procedures which would enable measurements of gross physiological and morphological changes.

Defruiting was performed to increase carbohydrates in the stalk and perhaps thereby to affect stalk rot resistance. Since total dissolved solids had been shown to be useful in previous studies of plant tissue as an estimate of sugar content, it was selected in preference to chemical analysis because of simplicity and usefulness in estimating insoluble dry weight. Chemical analysis was used only to determine the reliability of total dissolved solids as a measure of various carbohydrate fractions.

Stalk rot response for normal plants was obtained from adjacent plots included in stalk rot experiments conducted by Dr. A. L. Hooker. The stalk rot response of defruited plants was obtained from this experiment. Poor stands prevented a good estimate of the latter.

The dates of silking of each variety are given for each replicate in Table 11 in the Appendix. Defruiting of rows of variety Wf9 designated to receive such treatment was performed July 27. Because of the interference of the sample date on August 4, all other varieties were defruited on August 6.

Stalk rot ratings of ten normal plants per replicate of the six varieties inoculated August 13 were obtained on September 13 from the adjacent four replicate experiments and were as follows: B2, 1.2; B14, 1.0; Wf9, 2.0; 38-11, 3.1; Ph41, 3.0, and OS420, 4.5. The ratings for defruited plants inoculated August 13 and rated September 18 are given individually and as field averages in Table 1.

In this year, normal plants of varieties B2 and B14 were considered to be resistant; those of Wf9 tended to be resistant; those of 38-11 and Oh41 tended to be susceptible; and OS420 plants were susceptible. Rating of the latter at 4.5 indicated that about half of the plants were discolored in the internode above the point of inoculation. These ratings of the normal plants of the six varieties were considered to be representative of the reactions to inoculation

obtained in previous years.

In defruited plants, a tendency to lower stalk rot ratings was noted, but it was not considered to be significant except in OS420. Defruited plants of that variety rated 4 or less which indicated the restriction to spread into upper internodes by nodal tissue. It had been expected that the differences would be more striking. The limited number of samples in defruited plants, differences in location of normal and defruited plants, and the different dates of stalk rot rating for the two treatments do not permit critical evaluation of the defruited stalk rot data. However, on the basis of limited samples, it is assumed that no significant differences in ratings occurred with the possible exception of OS420.

The remainder of the 1954 results are based on the maximum number of three stalks sampled per replicate of normal plants and two per replicate of defruited plants. This was not always the case due to diseased or insect damaged tissue discovered in the processing of samples, more samples being discarded in late sample dates than in early ones. The data for each group of replicate subsamples for each variety were summarized as replicate and field averages for all measurements. The replicate and field averages are given in the Appendix. Data and figures derived from field averages are given in this section.

Table 1. Individual stalk rot ratings and field averages of defruited plants inoculated August 13 and rated September 18, 1954

Variety	Stalk rot rating			
	Replicate 1	Replicate 2	Replicate 3	Field average
Wf9	1, 1	3, 2	3, 1, 1	1.7
38-11	3, 3, 3	2, 2, 2	1, 3, 3	2.4
Oh41	2, 3	4, 4, 3	2, 3	2.9
OS420	4, 4, 4	---	3, 3	3.5
B2	1, 1, 1	1, 1	1, 1	1.0
B14[a]	2, 2, 2, 1	1, 2, 1	1, 2, 1	1.5

[a]Variety B14 stalks rated 2 for stalk rot include the atypical area of discoloration and would have been rated 1 if only the typical area were rated.

Moisture on a fresh weight basis

The data for the six varieties and the two treatments are given in Table 12 in the Appendix and presented graphically in Figures 3 and 4. Defruiting tended to decrease the moisture percentage in all varieties, especially in late August. In both treatments in early August and early September, the resistant variety B14 and variety Wf9, which tended to be resistant, had the lowest moisture percentage; the two varieties, 38-11 and Oh41, which tended to be susceptible had the highest moisture percentage; and the resistant variety

Figure 3. Seasonal trend in field averages of moisture percentage on a fresh weight basis for normal plants of the six varieties in 1954. Replicate and field averages are given in Table 12 in the Appendix.

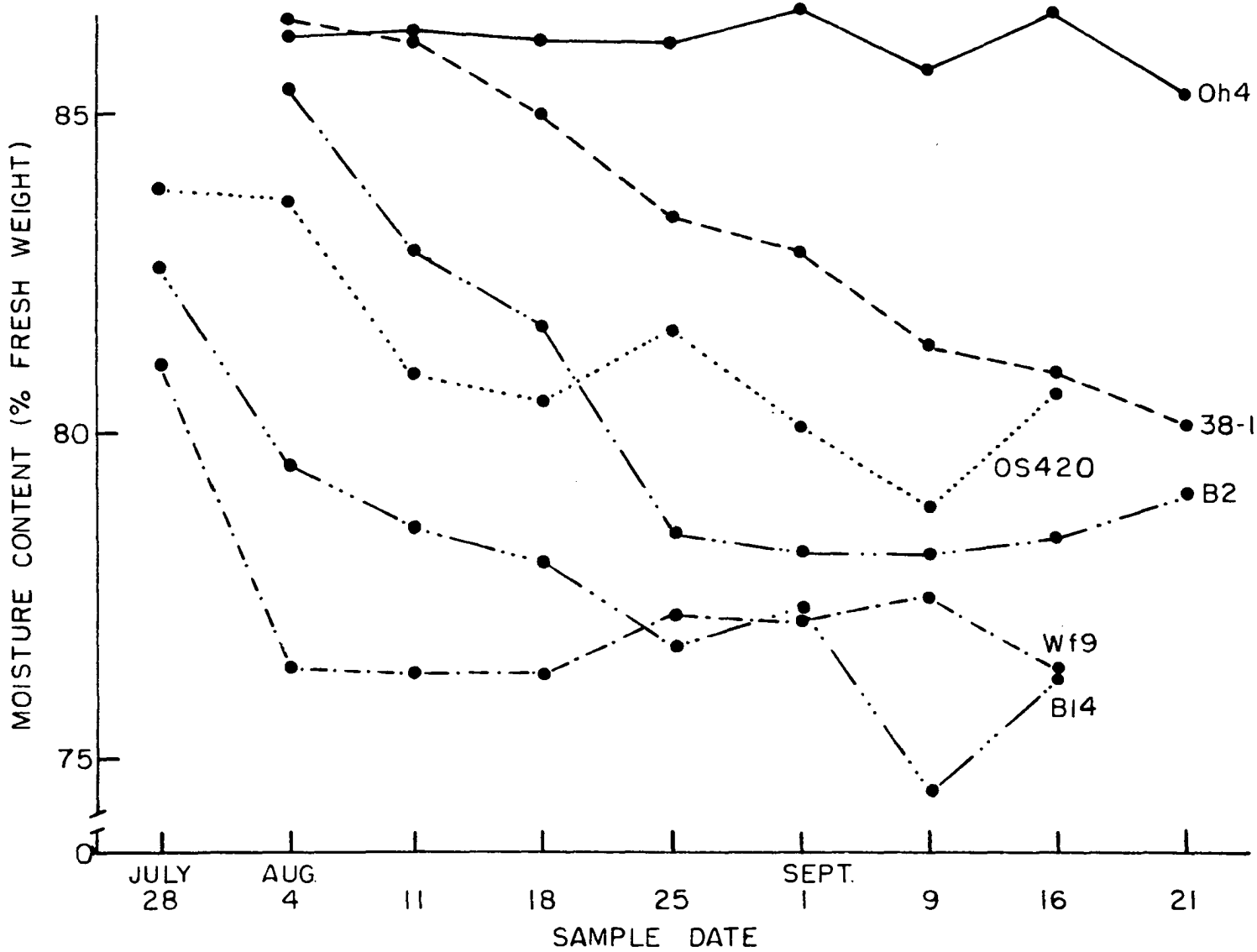
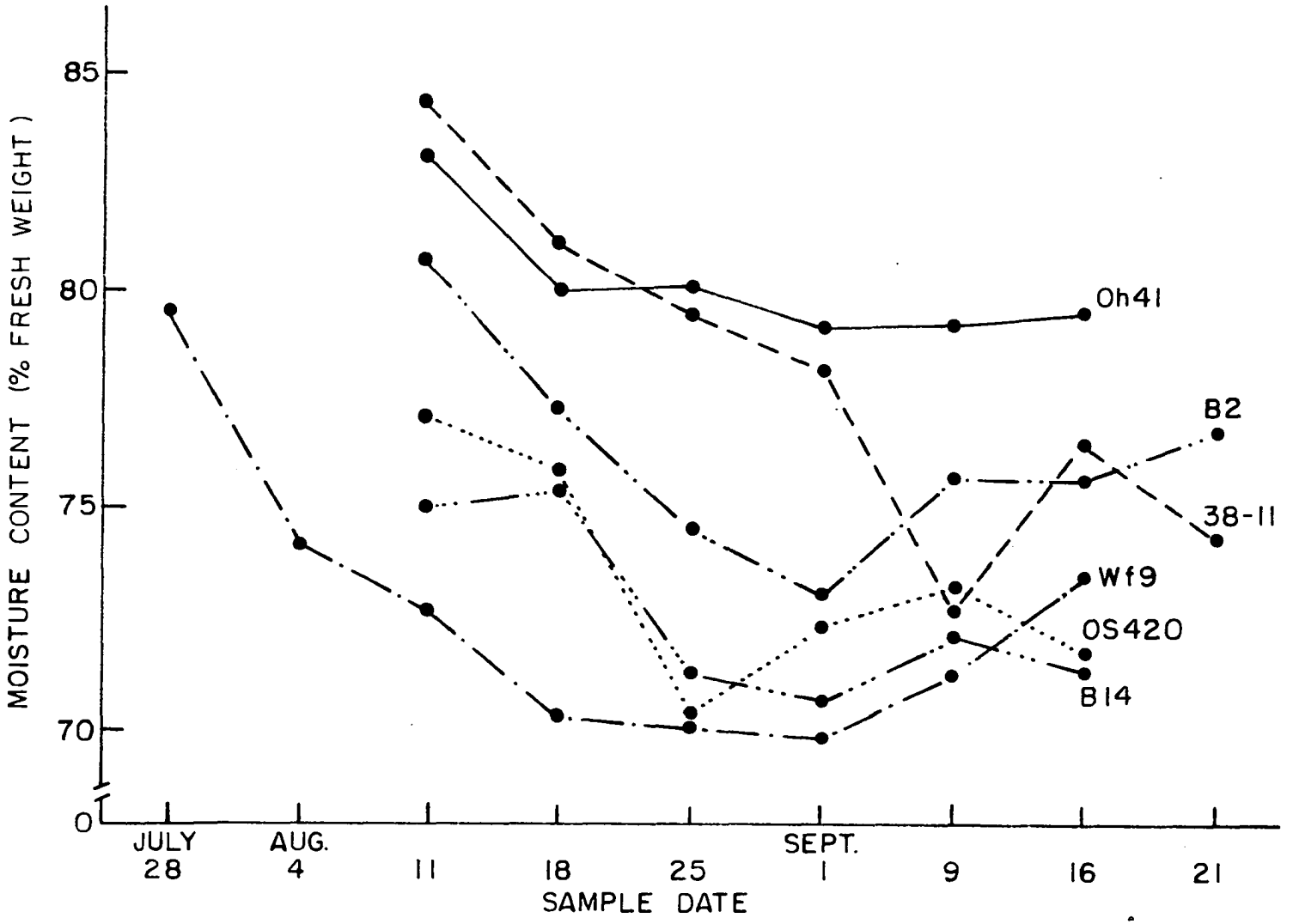

MOISTURE CONTENT (% FRESH WEIGHT)
85
80
75
0
JULY
28
AUG.
4
11
18
25
SEPT.
1
9
16
21
SAMPLE DATE
Oh41
38-11
OS420
B2
Wf9
B14

Figure 4. Seasonal trends in field averages of moisture percentage on a fresh weight basis for defruited plants of the six varieties in 1954. Replicate and field averages are given in Table 12 in the Appendix.


MOISTURE CONTENT (% FRESH WEIGHT)
85
80
75
70
0
JULY
28
AUG.
4
11
18
25
SEPT.
1
9
16
21
SAMPLE DATE
Oh41
B2
38-11
Wf9
OS420
B14

B2 and the susceptible variety OS420 had intermediate levels of moisture. This condition was modified in late September by a drop to an intermediate level by normal plants of 38-11 and by a rise in defruited plants of B2 and a drop in the defruited plants of OS420. Had OS420 been highest in moisture percentage, an arrangement from susceptible to resistant plants would have evolved with normal plants. In defruited plants, OS420 tended to follow the pattern of B14, while B2 increased in moisture to about the level of the varieties which tended to be susceptible. It was concluded that no clear relationship existed between percentage of moisture and stalk rot ratings.

Total dissolved solids

The per cent of total dissolved solids in expressed juice from pith pieces of the second internode above the uppermost brace roots of normal and defruited stalks was determined using a hand refractometer. The results are given in Table 12 in the Appendix. It was assumed that the percentage total dissolved solids in the second internode was comparable to that of the first internode and that any difference would be small compared to those among varieties required for significance in relation to disease resistance. On this assumption, the percentage data were used to calculate the amount of total dissolved solids per cc. of first internode stalk tissue. The results of the calculations

are given in Table 12 in the Appendix. The calculations were made as follows:

$$\text{mg. TDS per cc.} = \frac{FW \times \%M \times \%\ TDS}{V \times 10^7}$$

mg. TDS per cc. = mg. of total dissolved solids per cc. of first internode tissue

FW = g. of fresh weight of the first internode

% M = moisture percentage of the first internode

% TDS = per cent total dissolved solids of the second internode

V = volume of the first internode in cc.

A comparison of changes in per cent total dissolved solids with time and mg. total dissolved solids per cc. of tissue points out the similarity of trends shown by these two methods of presenting this data for both normal and defruited treatments. The data for normal plants are shown graphically in Figures 5 and 7 and for defruited plants in Figures 6 and 8. Some shifts in the curves are apparent. Of the two methods for evaluation of total dissolved solids data, the latter is more useful since it enables determination of mg. insoluble dry matter per cc. of tissue with little additional effort.

Normal plants of variety Wf9 peaked in percentage and mg. total dissolved solids about two weeks after silking and then dropped off slowly. Normal plants of this variety were highest in both percentage and mg. total dissolved solids per

Figure 5. Seasonal trend in field averages of per cent total dissolved solids of expressed stalk sap for normal plants of the six varieties in 1954. Replicate and field averages are given in Table 12 in the Appendix.

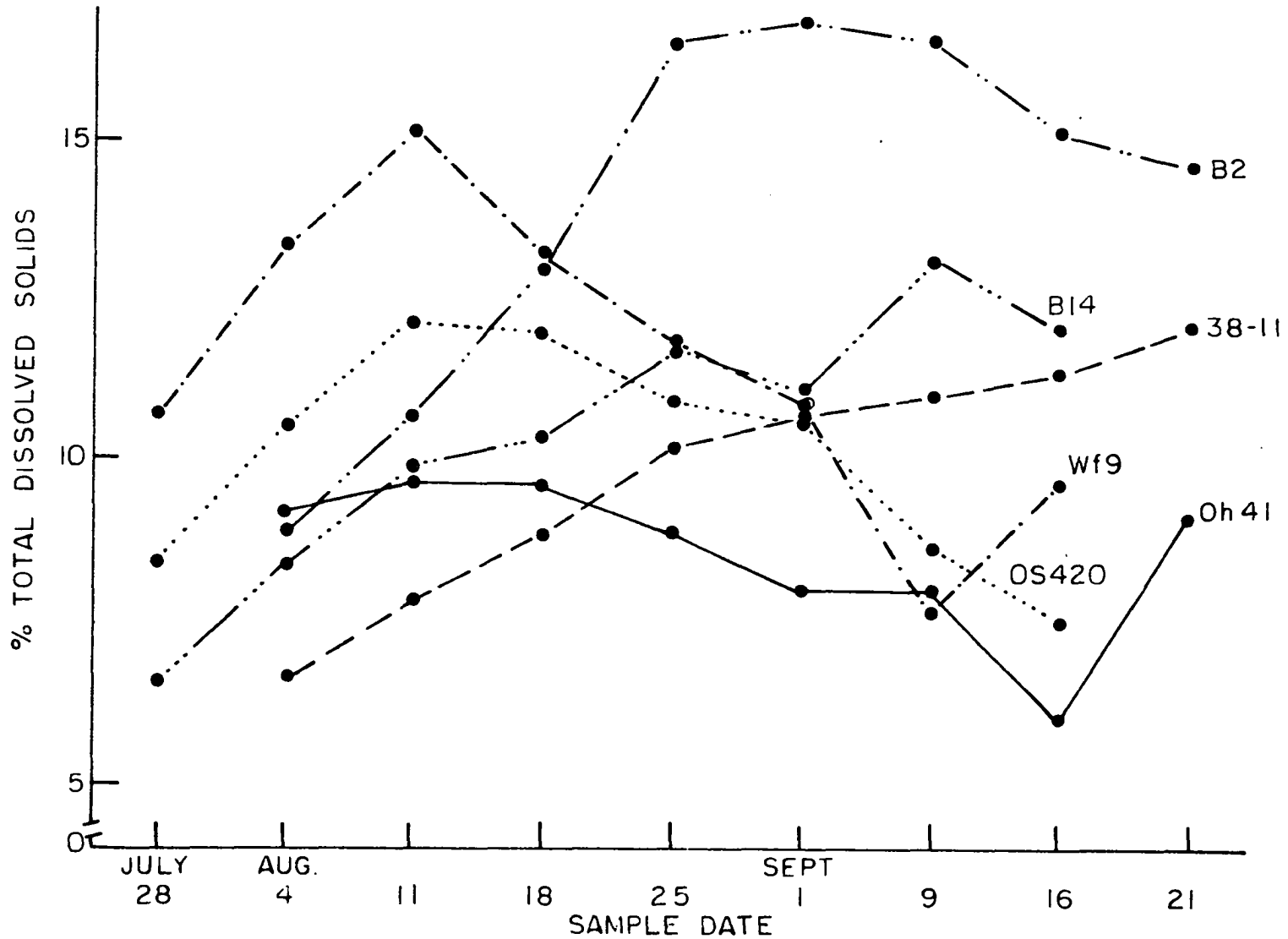

% TOTAL DISSOLVED SOLIDS
15
10
5
0
JULY
28
AUG.
4
11
18
25
SEPT
1
9
16
21
SAMPLE DATE
B2
B14
38-11
Wf9
Oh 41
OS420

Figure 6. Seasonal trends in field averages of per cent total dissolved solids of expressed stalk sap for defruited plants of the six varieties studied in 1954. Replicate and field averages are given in Table 12 in the Appendix.

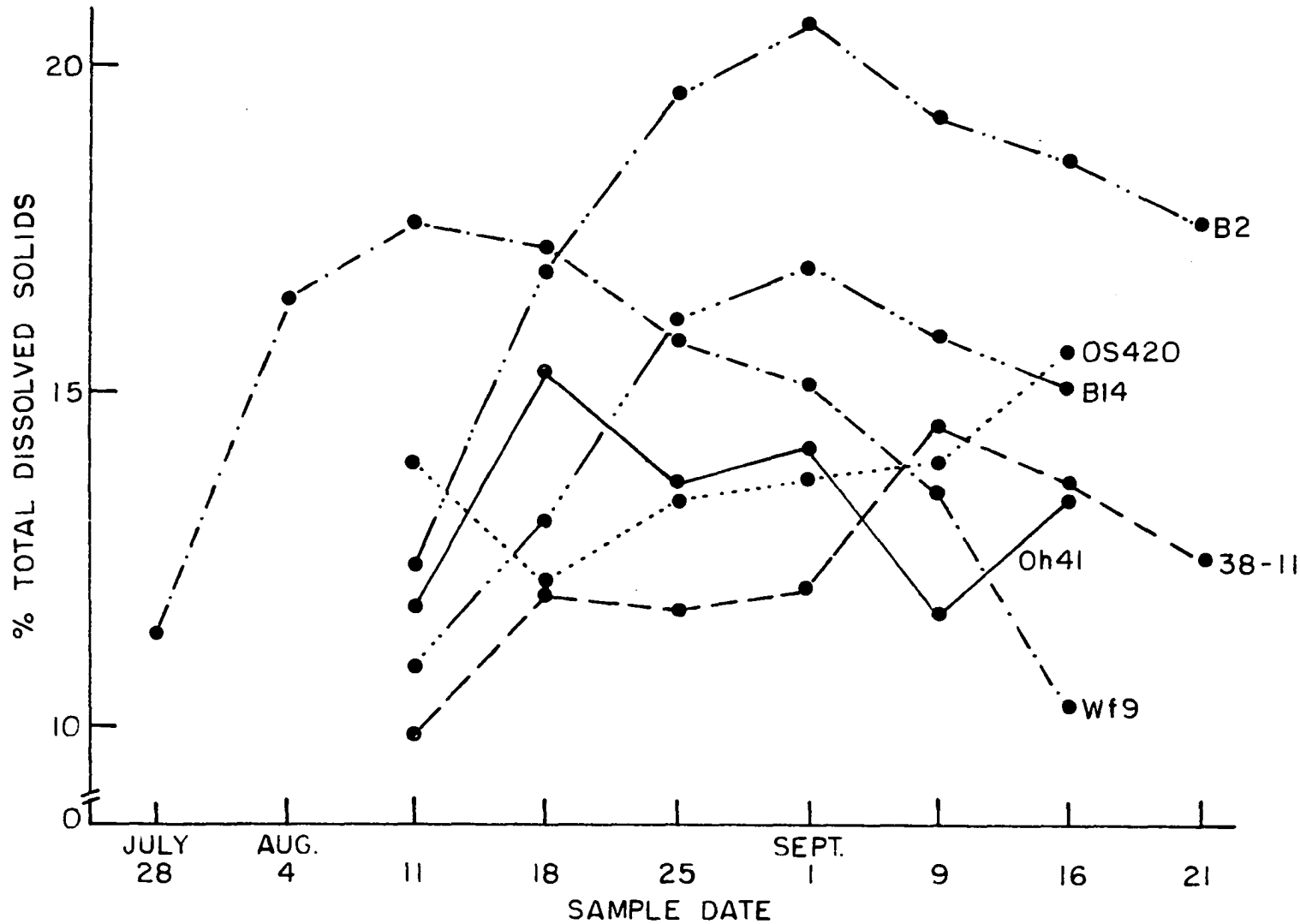

% TOTAL DISSOLVED SOLIDS
20
15
10
0
B2
OS420
B14
Oh41
38-11
Wf9
JULY
28
AUG.
4
11
18
25
SEPT.
1
9
16
21
SAMPLE DATE

Figure 7. Seasonal trend in field averages of mg. total dissolved solids per cc. for normal plant tissue of the six varieties in 1954. Replicate and field averages are given in Table 12 in the Appendix.

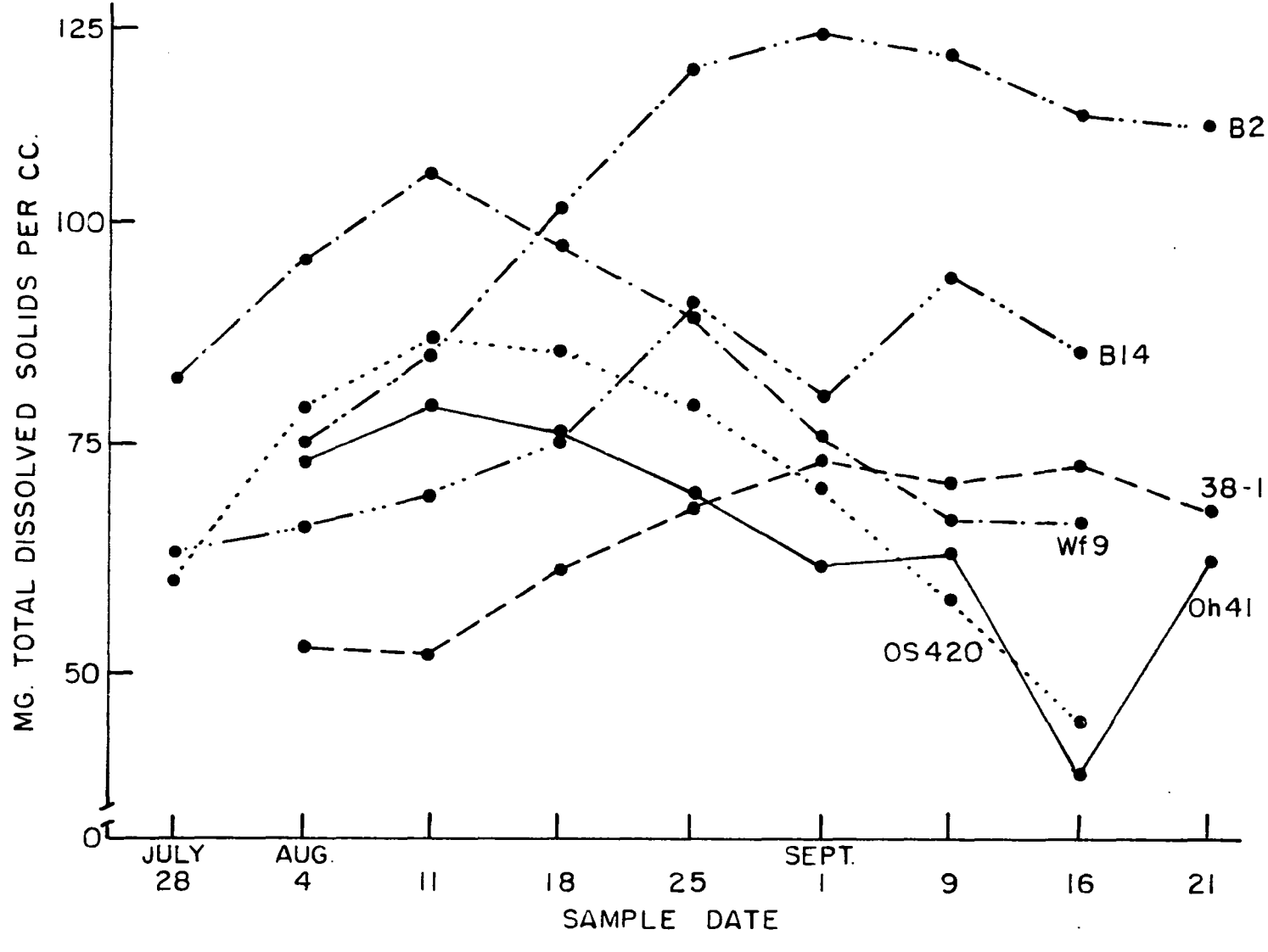
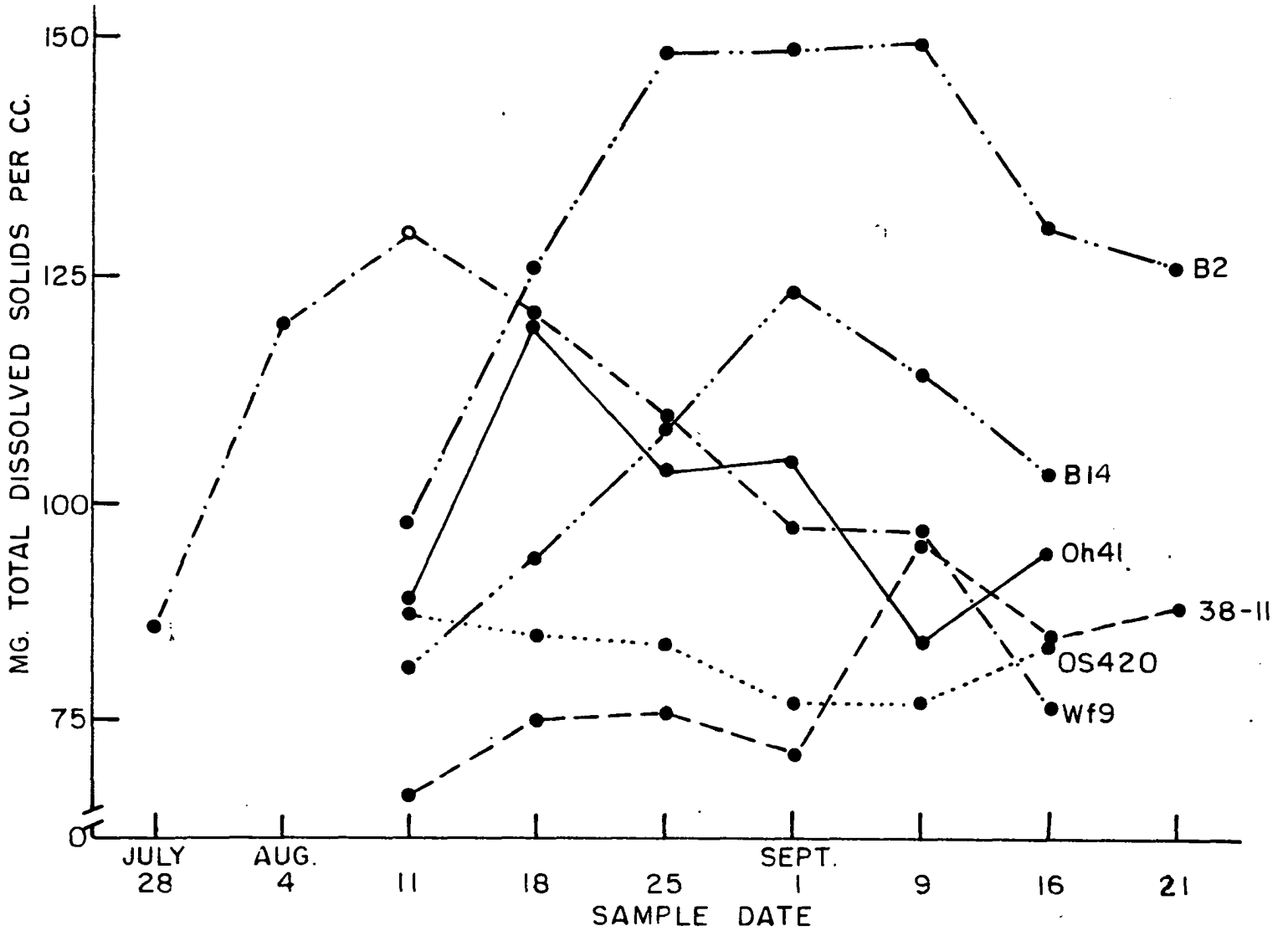

MG. TOTAL DISSOLVED SOLIDS PER CC.
125
100
75
50
0
JULY
28
AUG.
4
11
18
25
SEPT.
1
9
16
21
SAMPLE DATE
B2
B14
38-11
Wf9
Oh41
OS420

Figure 8. Seasonal trend in field averages of mg. total dissolved solids per cc. for defruited plant tissue of the six varieties in 1954. Replicate and field averages are given in Table 12 in the Appendix.


150
125
100
75
0
MG. TOTAL DISSOLVED SOLIDS PER CC.
B2
B14
Oh41
38-11
OS420
Wf9
JULY
28
AUG.
4
11
18
25
SEPT.
1
9
16
21
SAMPLE DATE

cc. during late July and early August and had dropped to an intermediate position in mid-September, the latter approximating the starting level. Normal plants of OS420 peaked for both percentage and mg. total dissolved solids per cc. about two weeks after silking and dropped off very slowly throughout the remainder of the experimental period, approximating the starting level by early September. Normal plants of Oh41 indicated a slight increase and peaked in percentage and mg. total dissolved solids per cc. in less than two weeks following silking and then decreased slowly reaching an apparent low point on September 16. At that date this variety was lowest by both methods of presenting the data. These three varieties, Wf9, OS420, and Oh41, represented a wide range of stalk rot ratings and were characterized by peaks by mid-August and decreases thereafter.

Normal plants of variety B2 peaked September 1, about five weeks after silking, in both percentage and mg. total dissolved solids per cc., and held these high levels for the remainder of the experimental period. This variety was highest by both indices for all dates following August 18. Variety B14 approximated this trend peaking September 9, about six weeks after silking, in both percentage and mg. total dissolved solids per cc. and ranked second highest in early September. Variety 38-11 also followed this trend peaking September 1, about four weeks after silking, in both indices and remained at these levels throughout the remainder of the

experimental period ranking third from September 1. Variety 38-11 was intermediate in both percentage and mg. data for normal plants. The trends in total dissolved solids data of normal plants of these six varieties, on both percentage and the mg. per cc. basis, were not well related to stalk rot ratings.

Defruiting increased the totaldissolved solids during the later stages of growth in all varieties and shifted peaks to higher levels. Defruited plants peaked about the same dates as normal plants and trends of percentage and mg. per cc. data in defruited plants were similar to those for normal plants.

In general, the normal plants of the resistant varieties, except Wf9, were higher in total dissolved solids per cc. at the date of stalk rot rating and peaked later than did the susceptible varieties. The peak of Wf9 occurred about the time of inoculation and was very high. This may in some way be involved in its tendency to be resistant even though it drops off in total dissolved solids rapidly after this time. It was concluded that while carbohydrates, as measured by total dissolved solids, may be indirectly related to stalk rot rating that no apparent correlation existed between these two indices in normal and defruited plants.

Relation of chemical analysis of sugars and total dissolved solids

The purpose of the sugar analyses was to determine the correlation between sugar fractions and total dissolved solids on selected dates. The averages of the results for any date samples are given in Table 13 in the Appendix. For convenience, the averages for total dissolved solids, as well as the reducing sugars, sucrose and total sugars, for the stalk samples analyzed are given in mg. per cc. of tissue. The correlation coefficients are given in Table 2.

Although both total sugars and sucrose were highly correlated with total dissolved solids on an mg. per cc. basis, the best correlation was with total sugars. Van Reen and Singleton (89) reported good correlation between Brix readings and sucrose content of the stalk juice of five inbreds sampled from the late whorl stage through the seventh week after pollination. The authors stated that Brix readings may not be reliable estimates of sucrose concentrations in all inbreds since some may store more of their total sugars as hexose rather than as sucrose, or the concentrations of salts and other non-sugar components may vary. The wide range of correlation coefficient values shown for the three sugar fractions in Table 2 may be attributed to these variations. However, in the present study, reducing sugars remained at a fairly constant level in all varieties regardless of total sugar content. This observation is in general agreement with

Table 2. Correlation coefficients for the relationship between total dissolved solids and reducing sugars, sucrose, and total sugars expressed as mg. contained per cc. of stalk tissue.

Variety	Number of stalk samples analyzed	Correlation coefficients of sugars to total dissolved solids		
		Reducing sugars	Sucrose	Total sugars
Wf9	37	0.32	0.48**	0.73**
38-11	35	0.21	0.84**	0.89**
Oh41	29	0.63**	0.49**	0.79**
OS420	32	0.06	0.68**	0.79**
B2	35	0.39	0.83**	0.92**
B14	36	0.13	0.71**	0.84**

**Significant at the 1 per cent level.

earlier reports (8, 47). Since chemical determination of sucrose, reducing sugars, and total sugars did not provide a more suitable index of resistance than hand refractometer measurements, they were discontinued. Although Holbert, et al. (20) and DeTurk, et al. (8) associated high carbohydrate content of stalk tissue with stalk rot resistance, the present study would not appear to support such conclusions.

Total dry matter per unit volume

Calculations of total dry matter per cc. of stalk tissue were made by using first internode dry weights and volumes. These calculations later were used to estimate insoluble dry matter per cc. of tissue. The mg. total dry weight per cc. of stalk tissue was determined as follows:

$$\text{mg. DM per cc.} = \frac{\text{FW x sample DW}}{\text{V x sample FW x } 10^3}$$

mg. DM per cc. = mg. of dry matter per cc. of first internode tissue

FW = g. fresh weight of the entire first internode

sample DW = g. dry weight of the sample of first internode tissue

sample FW = g. fresh weight of the sample of first internode tissue

V = volume of the entire first internode in cc.

The data obtained from these calculations are given in Table 12 in the Appendix and shown graphically in Figures 9 for normal plants and 10 for defruited plants.

Total dry matter per cc. of tissue reached a peak in variety Wf9 about two weeks after silking in both normal and defruited plants. Although this level was not maintained, the decrease was very slow throughout the experiment and the variety ranked highest until late August. Variety B2 gained slowly in normal plants but rapidly in the defruited plants

Figure 9. Seasonal trend in field averages of mg. total dry matter per cc. for normal plant tissue of the six varieties in 1954. Replicate and field averages are given in Table 12 in the Appendix.

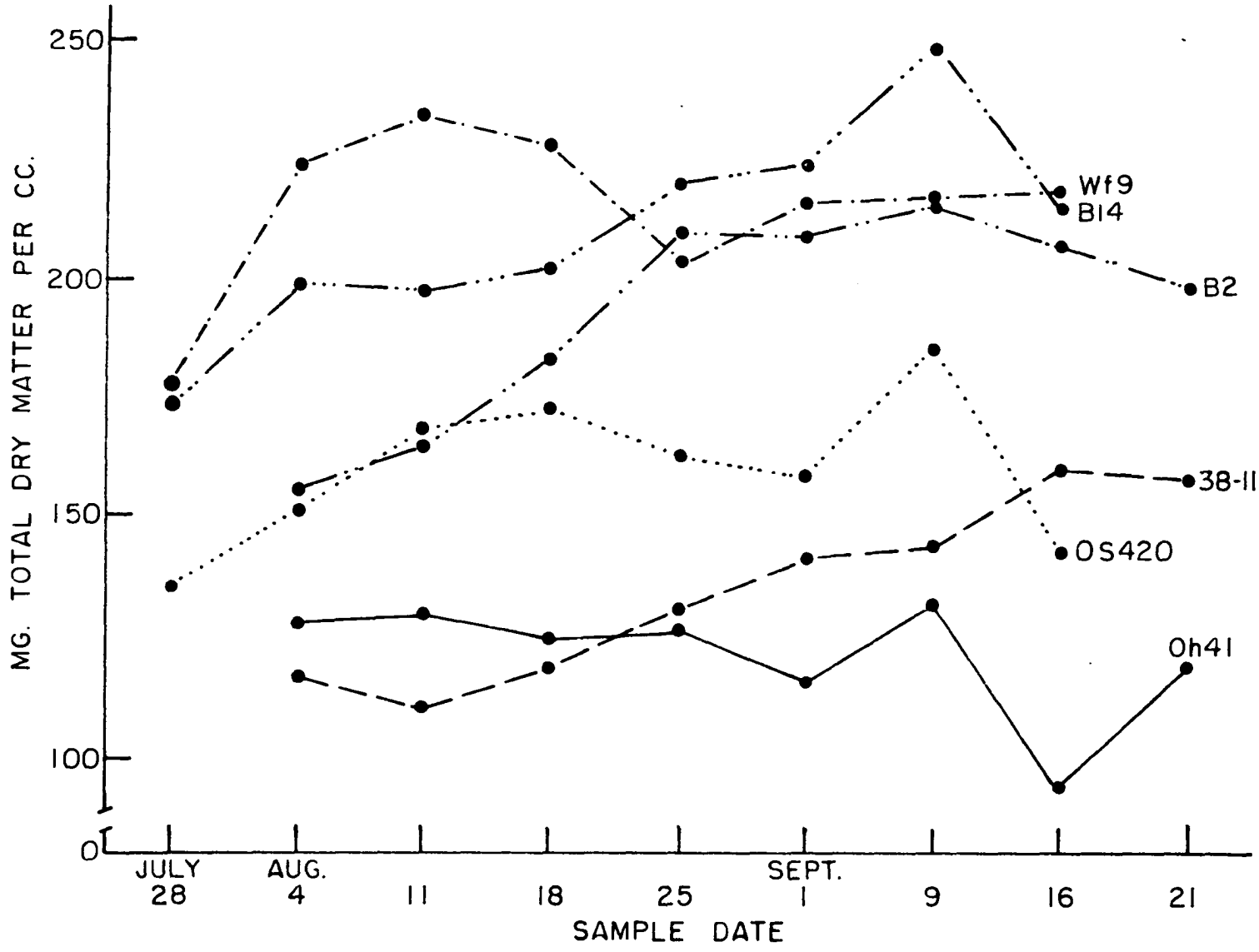
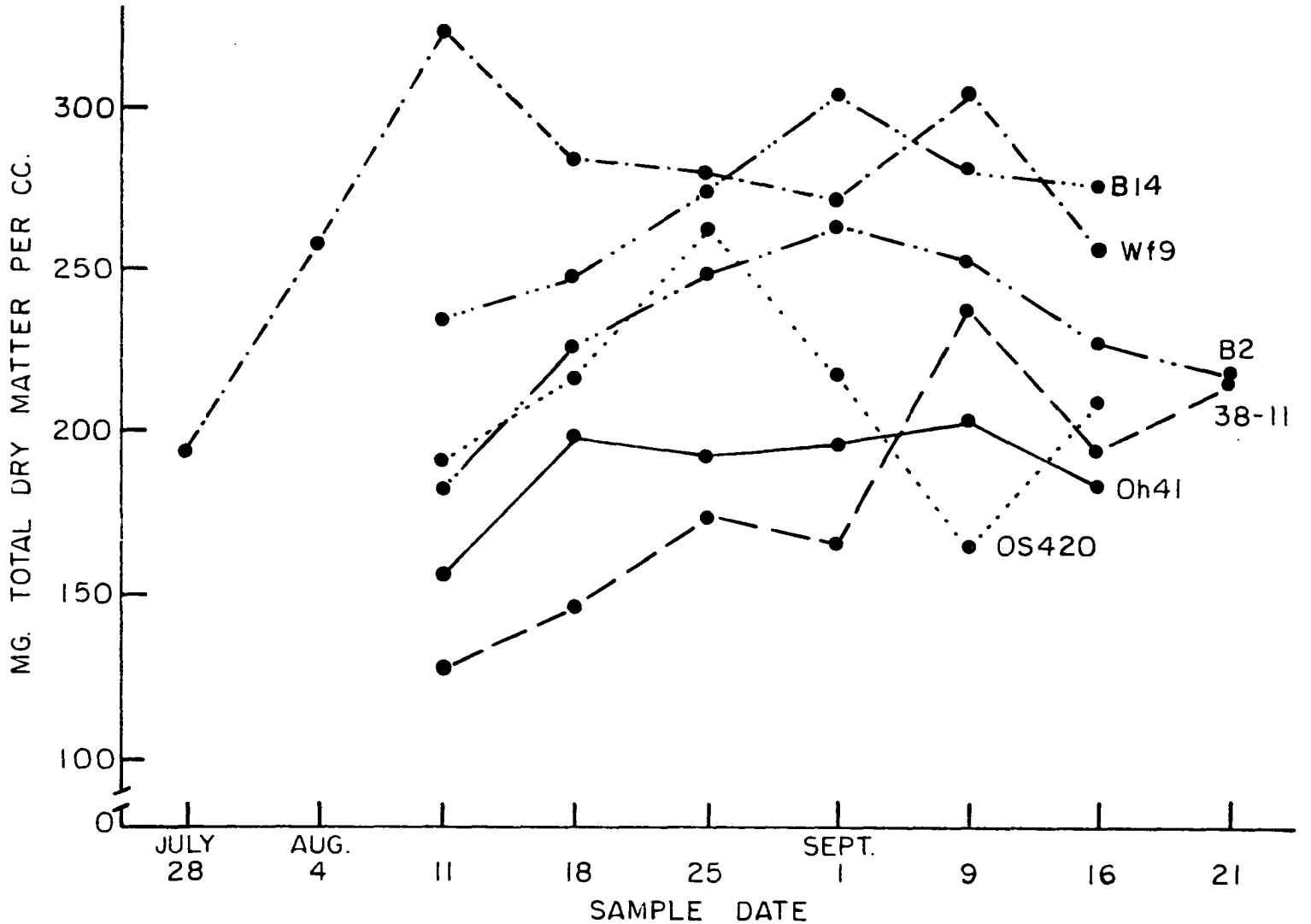

250
200
150
100
0
MG. TOTAL DRY MATTER PER CC.
Wf9
B14
B2
38-11
OS420
Oh41
JULY
28
AUG.
4
11
18
25
SEPT.
1
9
16
21
SAMPLE DATE

Figure 10. Seasonal trend in field averages of mg. total dry matter per cc. for defruited plant tissue of the six varieties in 1954. Replicate and field averages are given in Table 12 in the Appendix.


MG. TOTAL DRY MATTER PER CC.
300
250
200
150
100
0
JULY
28
AUG.
4
11
18
25
SEPT.
1
9
16
21
SAMPLE DATE
B14
Wf9
B2
38-11
Oh41
OS420

and peaked in both about five weeks after silking. Variety B14 slowly increased in both normal and defruited plants peaking about six weeks after silking. These three varieties formed a separate group in Figure 9 from August 25 to the end of the experiment and were clearly higher in dry matter content than the other varieties studied.

Total dry matter in mg. per cc. of OS420 normal plants maintained a fairly constant level from two weeks after silking to the end of the experiment while defruited plants peaked sharply about four weeks after silking and then dropped off rapidly. Normal plants of variety Oh41 remained at a constant level in the first three weeks after silking and then dropped off slowly while defruited plants gained slowly during the early period and peaked about six weeks after silking. Variety 38-11 increased slowly in both treatments reaching peaks about five to six weeks after silking. Normal plants of OS420 were at the middle of the range of mg. dry matter per cc. of tissue in early September while varieties Oh41 and 38-11 constituted the low group. In defruited plants, the shifts of 38-11 and OS420 on September 9 may be accounted for by biological variation and sampling. Defruiting increased the total dry matter content of the stalks in all varieties.

Had OS420 been lowest in both normal and defruited plants, an arrangement from resistant to susceptible varieties would have evolved. Since this was not the case, no clear cor-

relation existed between mg. total dry matter per cc. of stalk tissue and stalk rot ratings.

Insoluble dry matter per unit volume

The subtraction of mg. total dissolved solids from mg. total dry matter per cc. of stalk tissue gave an estimate of insoluble dry matter per cc. of stalk tissue. This index represented a gross measure of the structural components such as cellulose and lignin as well as reserve polysaccharides. The data obtained in this way are given in Table 3 and presented in Figures 11 and 12 for normal and defruited plants, respectively.

Normal plants of all varieties showed slow increases or no change in mg. of insoluble dry matter per cc. throughout the season. Three general groupings can be seen in Figure 11. The high group includes Wf9 and B14, the middle group includes OS420 and B2, and the low group includes Oh41 and 38-11. The latter shifted upward to the middle group in mid-September.

Defruiting increased insoluble dry matter of the stalks in all varieties. A general increase with time, showing greater variability in measurement in early September, occurred in all defruited plants except in OS420. In the latter a sharp peak occurred three weeks after silking. What this peak represents is not known, but it suggests rapid re-utilization of some material. In the defruited plants, only

Table 3. Field average for mg. insoluble dry matter per cc. of tissue of normal (N) and defruited (D) plants in 1954

Variety		Sample date								
		July 28	Aug. 4	Aug. 11	Aug. 18	Aug. 25	Sept. 1	Sept. 9	Sept. 16	Sept. 21
Wf9	N	95	126	130	132	118	138	149	150	---
	D	110	139	193	160	171	175	205	181	---
38-11	N	--	61	57	57	66	68	73	85	88
	D	--	--	63	71	95	94	143	109	126
Oh41	N	--	54	52	52	58	53	71	55	55
	D	--	--	66	78	87	91	120	86	--
OS420	N	77	72	81	87	82	87	125	99	--
	D	--	--	102	132	179	141	86	124	--
B2	N	--	78	85	81	88	85	92	94	87
	D	--	--	84	98	102	115	102	97	87
B14	N	110	133	128	125	132	143	156	130	--
	D	--	--	155	144	167	181	166	172	--

two general groups are apparent, a high group which includes Wf9 and B14 and a low group which includes Oh41, 38-11, and B2. This low group in defruited plants contained more insoluble dry matter per cc. of tissue than did the middle group of normal plants. Variety OS420 peaked at the high group level but decreased rapidly to the low group in early September. Since there are differences in insoluble dry matter magnitudes and trends in normal and defruited plants and no clear correlation existed between this measurement and stalk

Figure 11. Seasonal trend in field averages of mg. insoluble dry matter per cc. for normal plant tissue of the six varieties studied in 1954. Field averages, given in Table 3, were derived from field averages of mg. total dissolved solids per cc. and mg. total dry matter per cc. of normal plant tissue given in Table 12 in the Appendix.

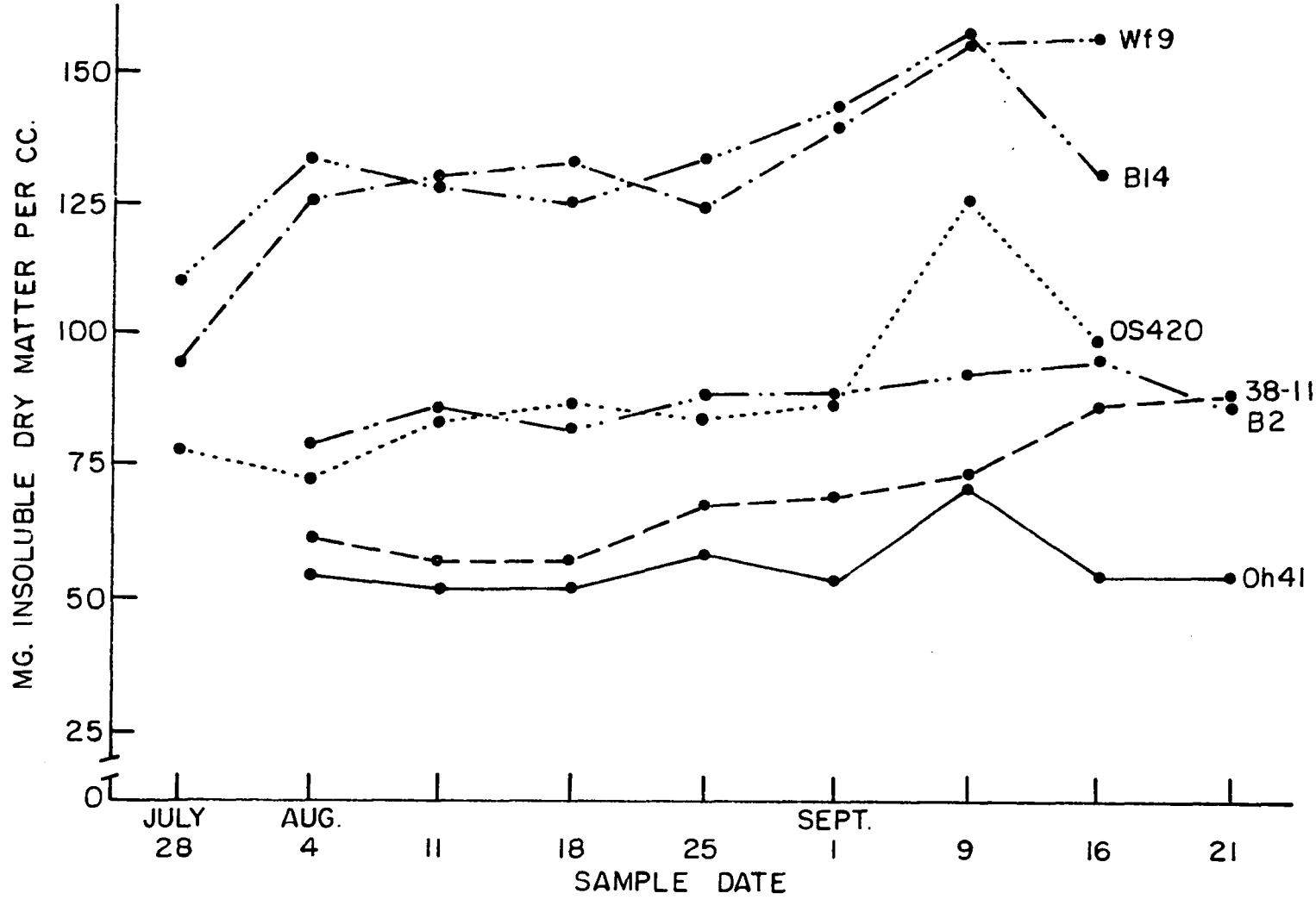
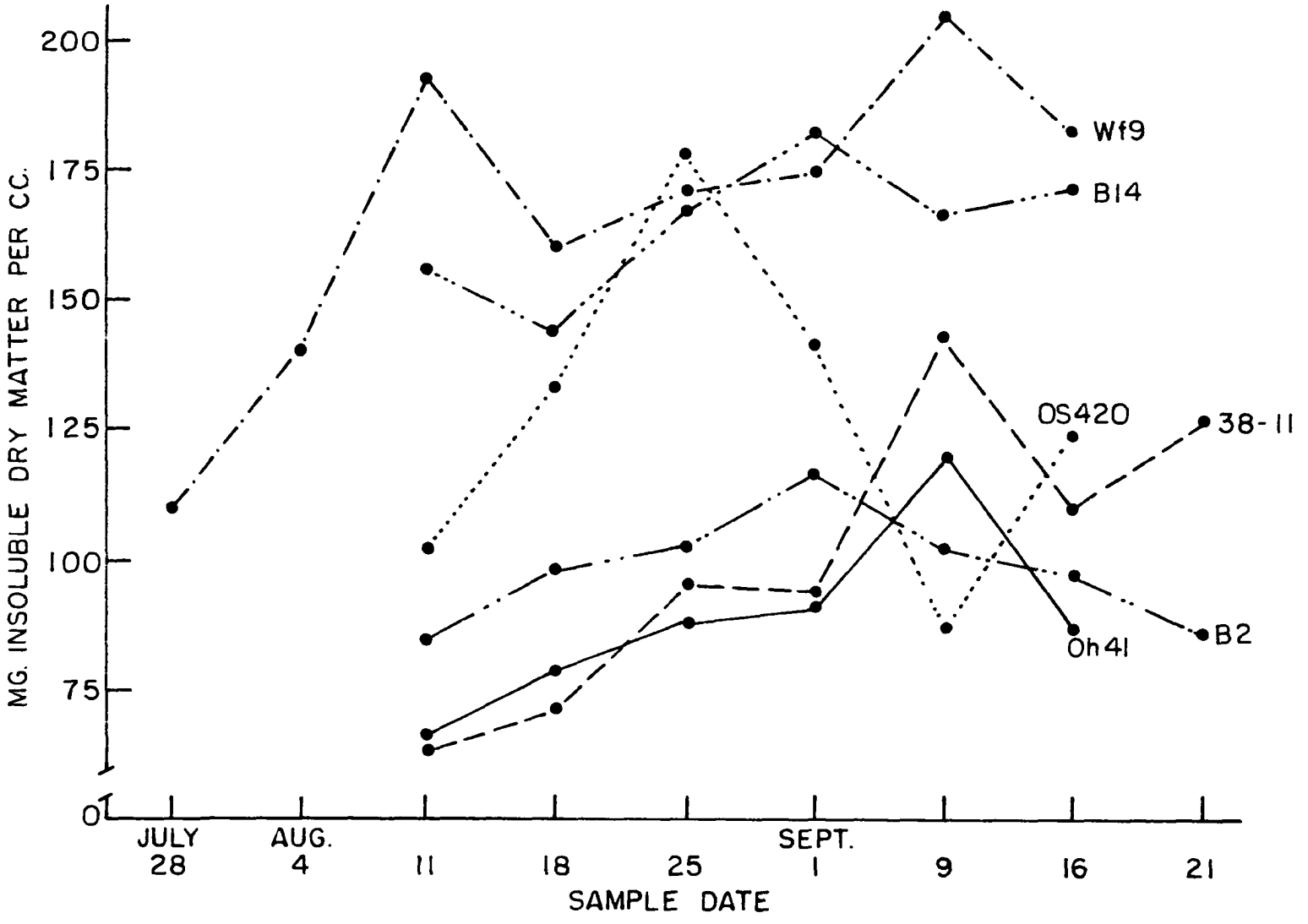

MG. INSOLUBLE DRY MATTER PER CC.
150
125
100
75
50
25
0
JULY
28
AUG.
4
11
18
25
SEPT.
1
9
16
21
SAMPLE DATE
Wf9
B14
OS420
38-11
B2
Oh41

Figure 12. Seasonal trend in field averages of mg. insoluble dry matter per cc. for defruited plant tissue of the six varieties in 1954. Field averages, given in Table 3, were derived from field averages of mg. total dissolved solids per cc. and mg. total dry matter per cc. of defruited plant tissue given in Table 12 in the Appendix.


MG. INSOLUBLE DRY MATTER PER CC.
200
175
150
125
100
75
0
JULY
28
AUG.
4
11
18
25
SEPT.
1
9
16
21
SAMPLE DATE
Wf9
B14
OS420
38-11
Oh41
B2

rot ratings, it does not appear to be a valuable index of resistance.

Experimental Results - 1955

The effects of rind thickness were believed to have influenced the observations made in 1954 since the measurements of all fresh weights and dry weights were on whole internodes. It appeared that the study of pith alone would lead to a better understanding and a possible orderly arrangement of resistant and susceptible varieties by one of the indices investigated in 1954. Furthermore, stalk rot data were required from the experimental plots containing field samples to enable correlation studies between the physiological measurements and stalk rot ratings. Since defruiting did not aid in obtaining a better understanding of disease resistance, only normal plants were studied. The emphasis in 1955 was placed on pith measurements, and whole internode observations of the same varieties were made on August 2, 23, and September 14 to enable comparison with 1954 results. It was apparent in 1954 that the pith tissue of susceptible plants was less completely hydrated than that of resistant plants. A better method for evaluating this observation was sought during this year's study.

The dates of silking of each variety are given for each replicate in Table 14 in the Appendix. Dates of silking were

not readily determined in all replicates due to the effects of hot dry weather on the plants at this stage of growth. Leaves of OS420 were severely affected by the heat as early as July 27, B14 was similarly affected by July 30, and all other varieties were showing heat damage in early August. A large number of plants of all varieties were barren or had very poor seed set.

In all results pertaining to stalk rot and pith condition ratings, the data presented for each replicate average for each variety represents the mean of ten samples. For all other data, a maximum of three samples per variety per replicate enter into the replicate averages. The replicate and field averages for 1955 measurements are given in the Appendix. Data and figures derived from field averages are given in this section.

Stalk rot and pith condition ratings

Stalk rot and pith condition ratings for the six varieties studied are presented in Table 4. Three experiments were undertaken to determine the stalk reaction to inoculation. The first experiment involved inoculation of the first internode of at least 20 plants in one row of each variety in each replicate on August 15. This row was then rated twice using ten plants on September 13 and on October 11. The purpose of this experiment was to determine whether plants increased in susceptibility with time and whether some physio-

Table 4. Replicate and field average for stalk rot and pith condition rating in 1955. Plants rated September 13 and October 11 were inoculated August 15. Plants rated September 22 were inoculated August 25. The replicate averages, both for stalk rot and pith condition, are based on ten stalk samples. (First internode = 1st, fourth internode = 4th)

Variety and replicate	Sept. 13	Sept. 22		Sept. 22		Oct. 11	
	1st	1st		4th		1st	
	stalk rot rating	Stalk rot rating	Pith cond. rating	Stalk rot rating	Pith cond. rating	Stalk rot rating	Pith cond. rating
Wf9							
1	1.2	1.6	2.1	3.4	4.0	2.5	2.8
2	2.7	3.2	3.3	4.0	4.0	4.2	3.8
3	2.1	3.7	3.6	3.3	4.0	2.3	2.8
Average	2.0	2.8	3.0	3.6	4.0	3.0	3.1
38-11							
1	2.5	1.9	2.6	3.6	3.9	3.8	3.5
2	2.9	3.6	3.7	4.1	4.0	4.0	3.9
3	-	-	-	-	-	-	-
Average	2.7	2.8	3.2	3.9	4.0	3.9	3.7
Oh41							
1	2.9	2.5	2.6	4.8	4.0	4.2	3.9
2	4.3	4.1	4.0	5.0	4.0	4.5	4.0
3	3.9	3.7	3.8	4.0	3.4	5.2	4.0
Average	3.7	3.4	3.5	4.6	3.8	4.6	4.0
OS420							
1	4.3	5.4	4.0	5.4	4.0	6.0	4.0
2	4.6	5.7	4.0	5.6	4.0	6.0	4.0
3	5.4	6.0	4.0	6.0	4.0	6.0	4.0
Average	4.8	5.7	4.0	5.7	4.0	6.0	4.0
B2							
1	1.0	1.4	1.2	1.9	3.8	4.1	3.8
2	3.1	4.1	3.6	4.0	4.0	6.0	4.0
3	1.8	4.2	3.7	4.0	3.8	4.3	3.5
Average	2.0	3.2	2.8	3.3	3.9	5.8	3.8
B14							
1	1.5	1.2	1.1	3.3	3.7	3.7	3.4
2	2.1	1.5	1.1	3.8	3.9	2.6	2.8
3	1.7	3.1	3.1	3.8	4.0	6.0	4.0
Average	1.8	1.9	1.8	3.6	3.9	4.1	3.4

logical measurement could be correlated with these changes. The second experiment also involved a 20 plant minimum per row of each variety per replicate. Ten plants were inoculated in the first internode and the remaining ten plants in the fourth internode on August 25, and all were rated September 22. The purpose of the experiment was to determine the reaction to inoculation in lower internodes and compare it to the reaction of upper internodes. The third experiment involved the first internode of ten plants in one row of each variety per replicate. These plants were inoculated September 30 and rated October 11 to determine the reaction of the first internode to late inoculation.

In the first experiment, the first rating was a preliminary test of the possibility that pith condition could be related in some way to stalk discoloration at that date by rating the former on the discoloration scale. In earlier sample dates, the condition of pith in the varieties studied was found to differ. In resistant varieties, the internodal pith was well hydrated and firm while in susceptible varieties the pith tended to be spongy and in later dates to become dry and crumbled on cutting. Only the pith tissue adjacent to the rind and node appeared hydrated in susceptible varieties. In intermediate varieties, the inner pith, which tended to be dry and have the characteristics of that in susceptible varieties, formed a vertical oval of lighter color extending upward and downward to the nodal tissue. The outer pith

tissue appeared well hydrated and was firm. The two conditions were readily visible when the internodes were cut lengthwise. It was this condition that was studied on the first rating date. These ratings are referred to as pith condition ratings.

On September 13, pith condition ratings were made in the internode above the inoculated internode using the same area scale as that used for discoloration ratings for stalk rot following inoculation. Although the actual pith condition ratings were not recorded, in every case good agreement was found between stalk rot and pith condition ratings. In subsequent stalk rot rating, the pith condition of the internode above the one inoculated was rated independently using the area scale. Since spread through the node could not be rated in pith condition studies, the stalk rot ratings of 5 and 6 were considered to be 4 for the purpose of the correlation analysis. This enabled a comparison of the discoloration reaction and pith condition, but the comparison was restricted to one internode. The stalk rot and pith condition ratings so obtained on October 11 were highly correlated, $r = 0.94$. This high correlation indicated that discoloration did not occur much beyond the marginal areas of the well hydrated tissue. Since good agreement existed in September and October ratings for first internodes, it was concluded that the spread of the organism, as represented by discoloration, was in some manner restricted by the well hydrated, firm pith

tissue. Spread through the node was not studied but was assumed to have occurred through the discolored vascular tissue which extended through the node. Evaluation of the data for the main purpose of this experiment yielded the fact that all varieties increased in susceptibility from mid-September to early October.

In the second experiment, stalk rot and pith condition ratings were recorded on September 22 both for first and fourth internodes. The pith condition ratings again were highly correlated with stalk rot ratings, $r = 0.89$. In this study, first and fourth internode data were pooled for the correlation analysis. The extent of stalk discoloration following inoculation was shown to be related to pith condition in the upper as well as lower internodes of the stalks of these six varieties. Only in the first replicate of variety B2 was the stalk rot rating of the fourth internode found to be less than 3. With that exception, all varieties were susceptible in the upper internode but varied in stalk rot ratings from resistant to susceptible in the lower internodes. In the third experiment on late inoculation, the discoloration reaction was very light, if it occurred at all, in the 11 days following inoculation. For that reason, no tabular data will be presented, but the reaction within each variety will be discussed. In variety Wf9, discoloration was very light and limited generally to the rind and vascular bundles at the point of inoculation. In the third replicate,

half of the inoculated stalks showed no discoloration. These stalks also rated 4 for pith condition. In the first and second replicates, discolored areas seldom exceeded 1 and 2 ratings for stalk rot and on the average rated about 3.5 for pith condition. When these light tan discolorations were compared with the dark brown to black areas observed in plants inoculated August 15 and rated on the same day as the plants in this experiment, the difference was very striking. This was true for all varieties. In variety 38-11, the light tan pigments in some plants were limited to the area of stalk inoculation and were primarily in rind tissue. Therefore, these plants were rated 1 for stalk rot. Two plants of the second replicate showed light tan color along the rind and nodal tissue and were rated 4 for stalk rot. The average pith condition rating for this variety was greater than 3.5. Only a few plants of variety Oh41 showed discoloration around the point of inoculation whereas the majority of the plants showed no discoloration. All internodes of this variety rated 4 for pith condition. No evaluation could be made on variety OS420 due to the extremely high rate of natural crown and stalk rotting. In variety B2, only a few plants discolored slightly and only at the inoculation point. In variety B14, only two out of 30 inoculated plants showed discoloration. Since the number of days after inoculation was small compared to earlier experiments concerning stalk rot, it was felt that time requirement for spread of the organism

in this tissue had not been sufficient. This is based on the observation that discoloration had occurred mainly on the rind tissue at the point of inoculation and only few varieties showed any tendency to discolor in rind tissue adjacent to nodes. In variety 38-11, only two plants showed discoloration along rind and nodal tissue. Hooker (22) reported that in susceptible varieties, the rate of spread was rapid in the first two weeks after inoculation but that satisfactory rating of plants required about a three but preferably a four week interval following inoculation. Roberts (43) reported that spread of the organism within the stalk was somewhat slower after late dates of inoculation than in early dates. In early dates, two weeks were required before discoloration occurred around the inside of the rind and margin of nodal tissue. It is concluded that the period following the late inoculation in the third experiment was not sufficient in duration. However, failure of the discoloration reaction to occur along vascular tissue and rind of many plants may be indicative of physiological changes in these stalks at this late date.

The ratings for stalk rot based on late inoculation would suggest that the plants became more resistant. The fact that all varieties increased in susceptibility from September 14 to September 22 and again from September 22 to October 11 points out the fact that this is not the case. Stalk rot ratings based on stalk discoloration following late inocula-

tion are not sufficient alone and should be accompanied by isolation techniques.

Data collected on October 11 indicating the percentage of natural crown rot in the field by replicates for each variety are given in Table 5. It further demonstrates that the plants were indeed susceptible. The occurrence of natural rotting in the crowns of the remaining uninoculated plants expressed as a percentage was highly correlated with stalk rot ratings on that date from plants inoculated on August 15, $r = 0.83$. This is in good agreement with the correlation coefficients between natural infection and cortical or pith spread after inoculation presented by Smith, et al. (50), $r = 0.85$ and 0.89, respectively. Stalks of all varieties were examined on October 11 to determine the pith condition rating of the first six internodes above the uppermost brace roots. In all plants of all varieties, the third and upper internodes rated 4 for pith condition. Only a few plants, usually of varieties Wf9, B14, and B2, had pith condition ratings of 2 for first internodes. Since stalk rot ratings were highly correlated with pith condition ratings and per cent natural crown rotting, it is suggested that pith condition ratings could be substituted for stalk rot ratings based on discoloration following inoculation and that both pith condition and stalk rot ratings were in some way related to natural rotting.

The stalk rot ratings obtained September 13 were used

Table 5. Natural crown rot of uninoculated plants determined October 11, 1955. Stalk rot ratings on that date are given for comparison

Variety and replicate	Crown rot			Stalk rot rating
	Number of plants		Per cent rotted	
	Observed	Rotted		
Wf9				
1	29	2	7	2.5
2	55	16	29	4.2
3	51	11	22	2.3
38-11				
1	18	1	6	3.8
2	45	9	20	4.0
3	-	-	-	-
Oh41				
1	26	4	15	4.2
2	43	17	40	4.5
3	33	22	67	5.2
OS420				
1	39	36	92	6.0
2	38	34	89	6.0
3	32	32	100	6.0
B2				
1	40	16	40	4.1
2	45	42	93	6.0
3	25	25	100	4.3
B14				
1	23	0	0[a]	3.7
2	49	3	6	2.6
3	34	27	79	6.0

[a]Although the percentage was zero, it was called one in computing the correlation coefficient.

to classify the six varieties for this year: Wf9, B2, and B14 tended to be resistant; 38-11 tended to be susceptible; Oh41 was susceptible, and OS420 was very susceptible. All varieties increased in susceptibility after this date. Many plants of variety OS420 had fallen in early September due to natural stalk rot, and by October 11 this variety was severely lodged in all replicates.

Moisture on a fresh weight and unit volume basis

The data for moisture percentage on the fresh weight basis for pith core and whole internode tissue are given in Table 15 in the Appendix and shown graphically in Figures 13 and 14. The moisture percentages of pith cores (Figure 13) were generally between 90 and 95 per cent on July 26 and in all varieties dropped slowly through August and early September. Variety B2 dropped from about 93 per cent on July 26 to 90 per cent on August 30 and to 86 per cent on October 4, being highest in moisture percentage after early August. Varieties 38-11 and B14 dropped from about 94 per cent on July 26 to about 83 per cent on September 14 and then remained at this level until October 4. Varieties Oh41 and OS420 followed similar patterns to mid August; both started at about 92 per cent on July 26, dropped to about 85 per cent on August 23, and then Oh41 dropped to about 80 per cent on September 14 while OS420 reached its low point of about 74 per cent on that date. Variety Wf9 was the lowest in moisture

Figure 13. Seasonal trend in field averages of moisture percentage on a fresh weight basis for pith core tissue of the six varieties in 1955. Replicate and field averages are given in Table 15 in the Appendix.

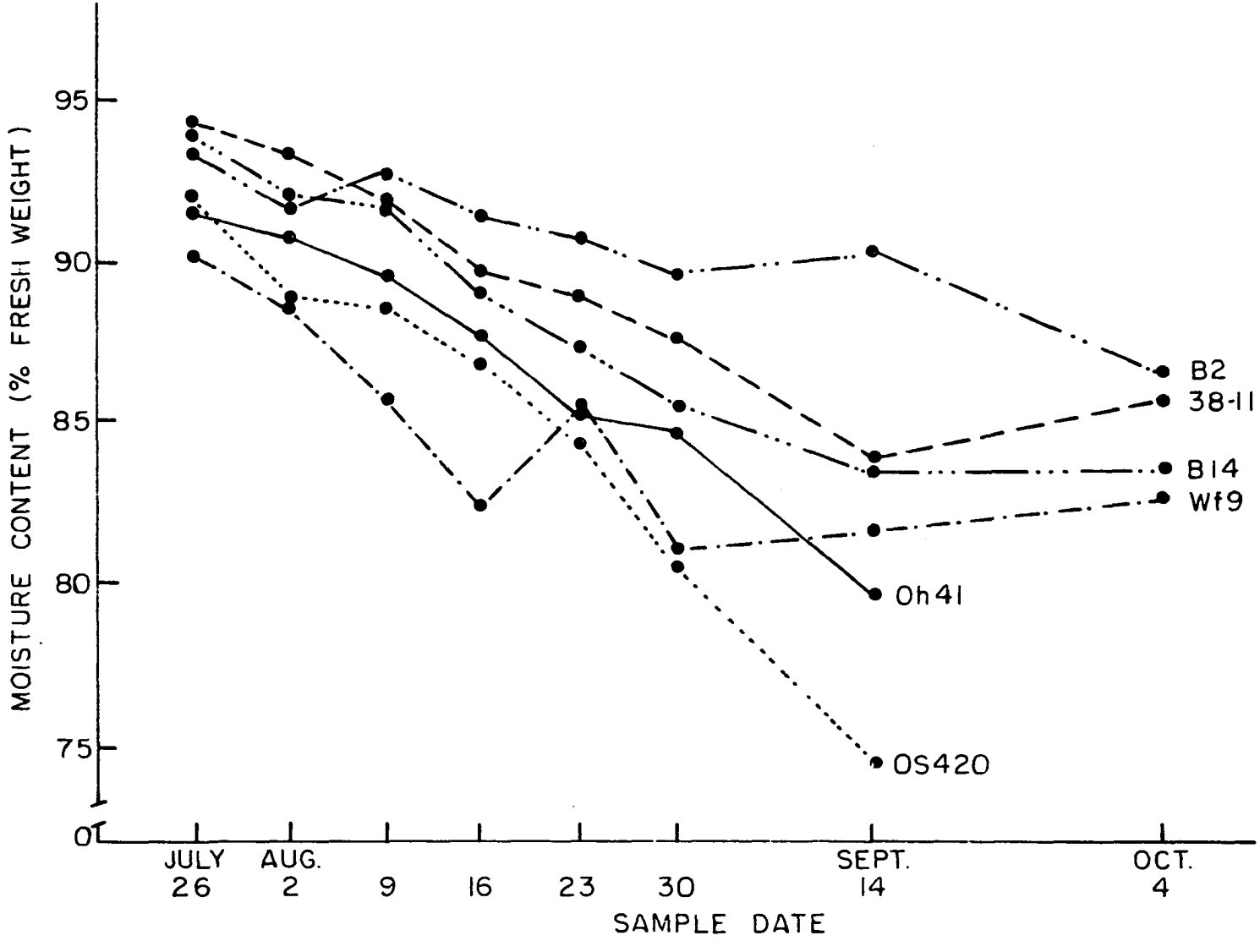
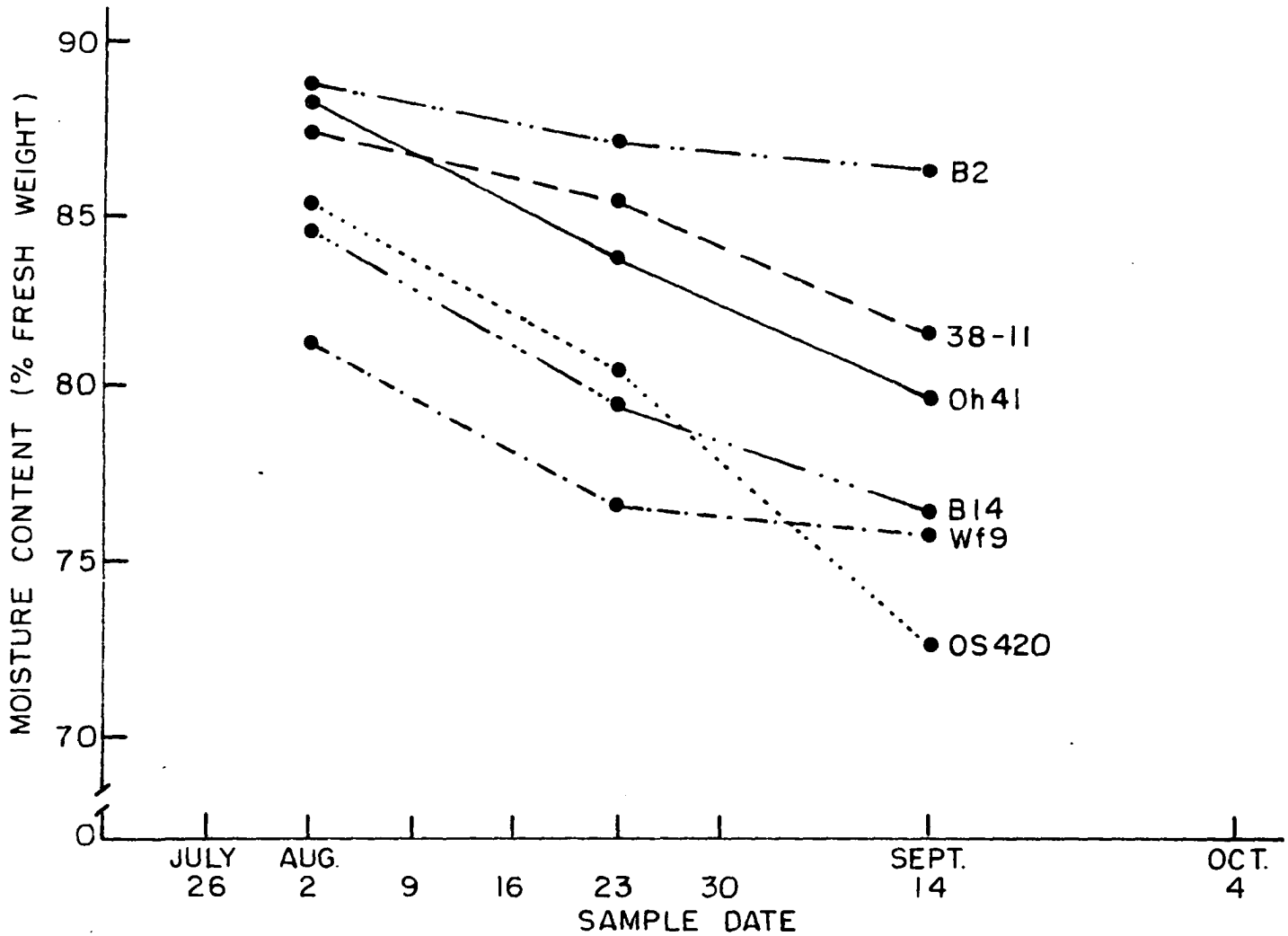

MOISTURE CONTENT (% FRESH WEIGHT)
95
90
85
80
75
0
JULY 26
AUG. 2
9
16
23
30
SEPT. 14
OCT. 4
SAMPLE DATE
B2
38-11
B14
Wf9
Oh41
OS420

Figure 14. Seasonal trend in field averages of moisture percentage on a fresh weight basis for whole internode tissue of the six varieties in 1955. Replicate and field averages are given in Table 15 in the Appendix.


MOISTURE CONTENT (% FRESH WEIGHT)
90
85
80
75
70
0
B2
38-11
Oh41
B14
Wf9
OS420
JULY 26
AUG. 2
9
16
23
30
SEPT. 14
OCT. 4
SAMPLE DATE

percentage through August; starting at about 90 per cent on July 26, dropped to about 81 per cent on August 30, and remained at that level until October 4. No clear relationship existed between moisture percentage levels of pith tissue or the seasonal trends and the stalk rot ratings.

Whole internode moisture content was determined at three of the eight sample dates, August 2, 23, and September 14 (Figure 14). The moisture percentage of whole internodes was generally lower than that of pith cores by a few percentage units. Variety B2 began at about 88 per cent on August 2 and was 86 per cent on September 14. Variety 38-11 started at about 87 per cent on August 2 and was about 81 per cent on September 14. Variety Oh41 started at about 90 per cent on August 2 and dropped to about 80 per cent on September 14. Variety OS420 started at about 85 per cent on August 2 and dropped to about 72 per cent on September 14. In these varieties the difference between moisture percentage of the whole internode and pith cones was about 3 to 6 per cent on August 2 and 1 to 4 per cent on September 14. In varieties Wf9 and B14, the whole internode and pith core moisture percentages differed by about 6 to 8 percentage units on both dates. These differences between whole internodes and their pith cores were not considered to be sufficiently great for significance. As in pith cores, there was no apparent correlation between whole internode moisture percentage and stalk rot ratings.

The moisture percentage on whole internodes in 1955 and those determined on normal plants in 1954 were in good agreement for all varieties. The differences in moisture percentage between 1954 and 1955 data were less than 10 percentage units.

Since the fresh weights among the pith cores of resistant and susceptible varieties appeared to differ greatly, and since water content accounts for the greater part of fresh weight, it appeared likely that a better method for expressing the apparent differences in moisture content would be water content per cc. of tissue. It was hoped that this basis of comparison would elucidate the obvious differences in well hydrated resistant tissue and spongy to dry susceptible pith tissue. The grams of water per cc. of pith tissue were calculated from field averages of two other measurements, grams of fresh weight per cc. of pith tissue, referred to as tissue density, and grams of total dry weight per cc. of pith tissue. The data are given in Table 6 and shown graphically in Figure 15.

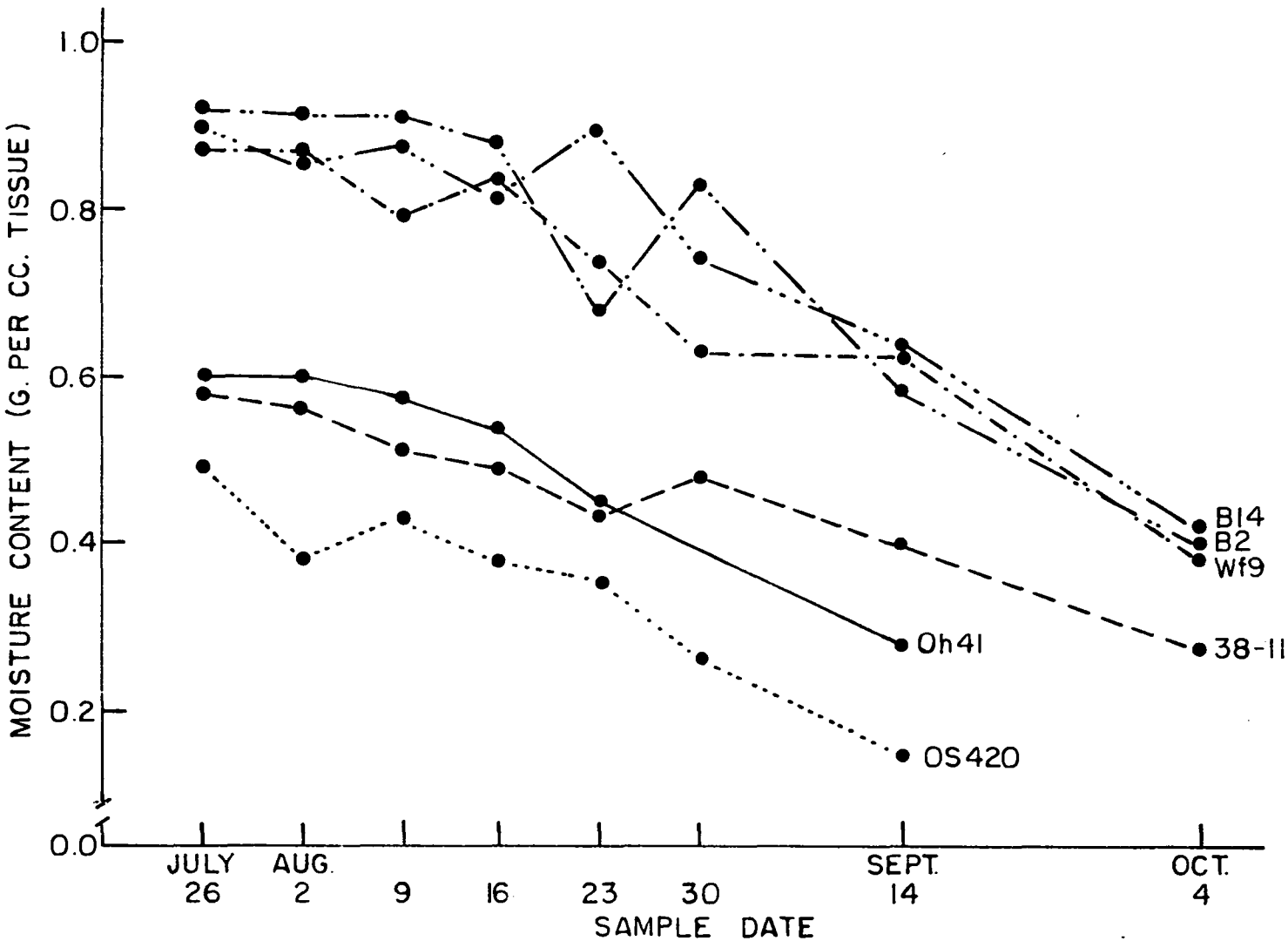
The results, in Figure 15, for pith core tissue shows three groups differing in water content but with similar trends through the season. The upper group, composed of variety Wf9, B2, and B14 were the highest at all dates and were resistant or tended to be resistant in September but increased in susceptibility by mid-October. The change in resistance was accompanied by a sharp drop in grams of water

Table 6. Field average for moisture content in grams of water per cc. of whole first internode (W) and pith core (P) tissue in 1955

Variety		Sample date							
		July 26	Aug. 2	Aug. 9	Aug. 16	Aug. 23	Aug. 30	Sept. 14	Oct. 4
Wf9	P	0.88	0.88	0.79	0.84	0.74	0.63	0.63	0.38
	W	--	0.77	--	--	0.77	--	0.70	--
38-11	P	0.58	0.56	0.51	0.49	0.43	0.48	0.40	0.27
	W	--	0.73	--	--	0.73	--	0.70	--
Oh41	P	0.60	0.60	0.57	0.54	0.43	--	0.28	--
	W	--	0.77	--	--	0.74	--	0.65	--
OS420	P	0.49	0.38	0.43	0.38	0.36	0.26	0.15	--
	W	--	0.60	--	--	0.51	--	0.33	--
B2	P	0.92	0.89	0.89	0.88	0.72	0.83	0.58	0.39
	W	--	0.82	--	--	0.82	--	0.72	--
B14	P	0.90	0.86	0.88	0.82	0.90	0.74	0.63	0.45
	W	--	0.78	--	--	0.80	--	0.75	--

per cc. of tissue and, as previously discussed, by a change in pith condition to one resembling the spongy dry to crumbly condition of the susceptible varieties. The three varieties contained about 0.9 g. of water per cc. of pith core tissue in late July. Variety Wf9 began to drop in this measurement in mid-August while B2 and B14 dropped sharply at late August dates. All three varieties ranged between 0.4 and 0.5 g. of water content in early October. The varieties 38-11 and Oh41 followed a similar trend to mid-August, but Oh41 then

Figure 15. Seasonal trend in field averages of water content measured as grams of water per cc. for pith core tissue of the six varieties in 1955. Field averages, given in Table 6, were derived from field averages of grams fresh weight per cc. (density) and mg. total dry matter per cc. of pith core tissue given in Table 15 in the Appendix.


MOISTURE CONTENT (G. PER CC. TISSUE)
1.0
0.8
0.6
0.4
0.2
0.0
JULY 26
AUG. 2
9
16
23
30
SEPT. 14
OCT. 4
SAMPLE DATE
B14
B2
Wf9
Oh41
38-11
OS420

dropped off sharply. Variety 38-11 tended to be susceptible while Oh41 was susceptible in early September. Both varieties were susceptible in October. Variety OS420 contained the least amount of water per cc. of tissue throughout the entire experiment. This variety dropped from about 0.5 to less than 0.2 g. of water per cc. of pith core tissue from July 26 to September 14 and was very susceptible at all dates and the majority of the plants were dead in October. The grams of water per cc. of pith core tissue were highly correlated with stalk rot ratings on September 14, r = 0.83. The data for each variety replicate average are given in Table 7 and presented graphically with the appropriate regression line in Figure 16. Varieties high in grams of water per cc. of tissue were resistant while those low in water content were susceptible. The increase in susceptibility from September to October was accompanied by a decrease in grams of water per cc. of pith core tissue and indicated that there may be a close relationship between water content of the tissue and pith condition ratings. The grams of water per cc. of whole internodes were determined in the same manner by subtracting the grams total dry matter per cc. of tissue from the density of the whole internode. Only two groups are apparent in Figure 17. The upper group is composed of varieties B2, B14, Wf9, 38-11, and Oh41. Variety OS420 was lowest throughout the season. Within the upper group there is some tendency for more resistant varieties to rank highest with

Table 7. Replicate average for density (grams fresh weight per cc.), water content (grams water per cc.) of whole first internode and pith core tissue on September 14, and stalk rot ratings on September 13, 1955. The replicate averages are based on three stalk samples for density and water content, and ten stalk samples for stalk rot ratings

Variety and replicate	Whole internode		Pith core		Stalk rot rating
	Density	Water content	Density	Water content	
Wf9					
1	0.94	0.71	0.70	0.57	1.2
2	0.93	0.69	0.69	0.55	2.7
3	0.93	0.71	0.71	0.59	2.1
38-11					
1	0.89	0.74	0.53	0.47	2.5
2	0.88	0.72	0.52	0.45	2.9
3	0.80	0.64	0.37	0.31	-
Oh41					
1	0.89	0.72	0.51	0.43	2.9
2	0.80	0.62	0.33	0.26	4.3
3	0.73	0.58	0.21	0.16	3.9
OS420					
1	0.57	0.43	0.24	0.20	4.3
2	0.49	0.37	0.22	0.17	4.6
3	0.28	0.18	0.10	0.06	5.4
B2					
1	0.96	0.82	0.86	0.78	1.0
2	0.67	0.57	0.36	0.32	3.1
3	0.90	0.79	0.71	0.65	1.8
B14					
1	1.05	0.78	0.96	0.79	1.5
2	1.02	0.75	0.82	0.67	2.1
3	0.89	0.71	0.50	0.43	1.7

Figure 16. Relationship between grams of water per cc. of whole internode and pith core tissue and stalk rot ratings for the six varieties on September 14, 1955. Each point represents the replicate average for these measurements given in Table 7.

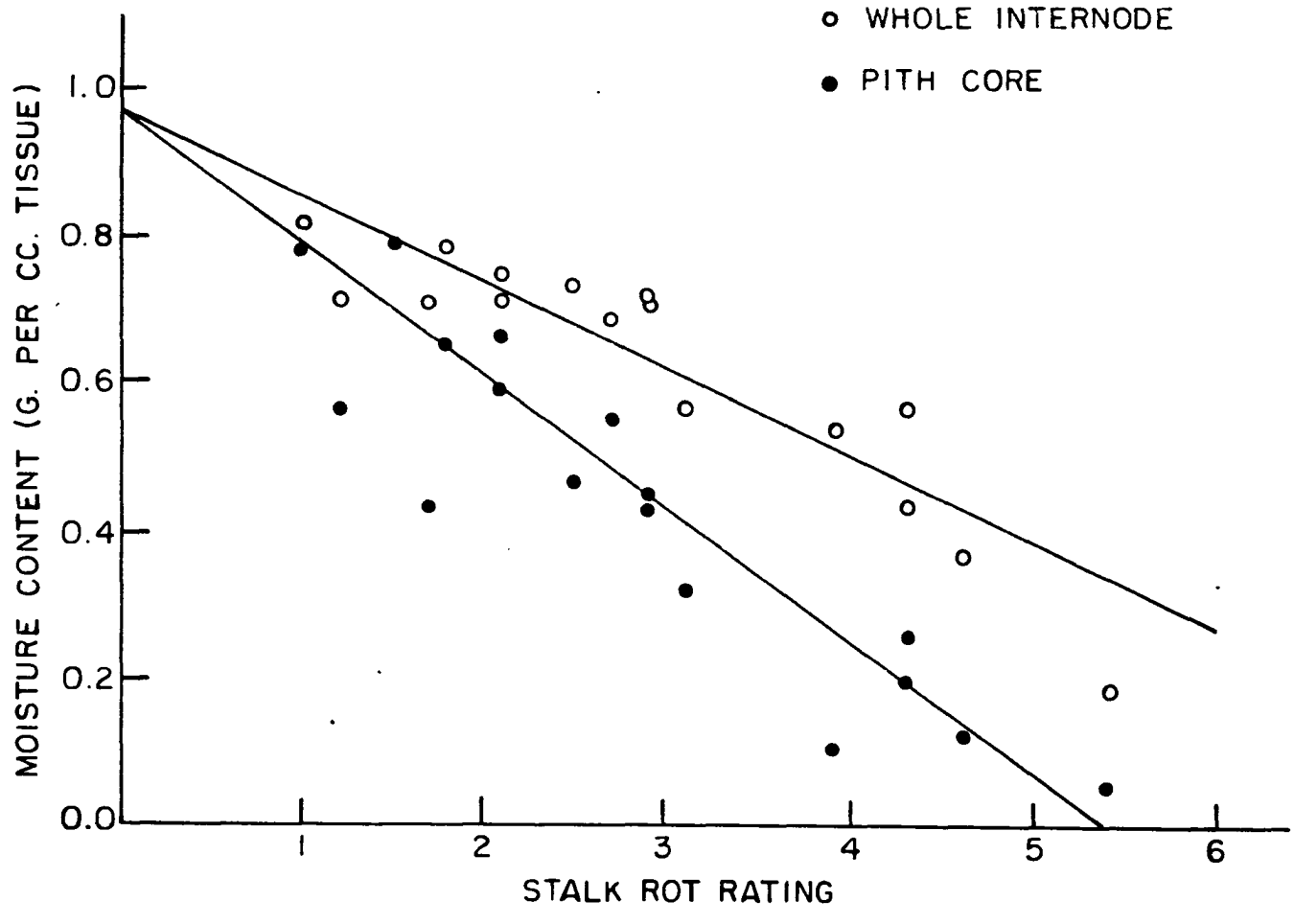
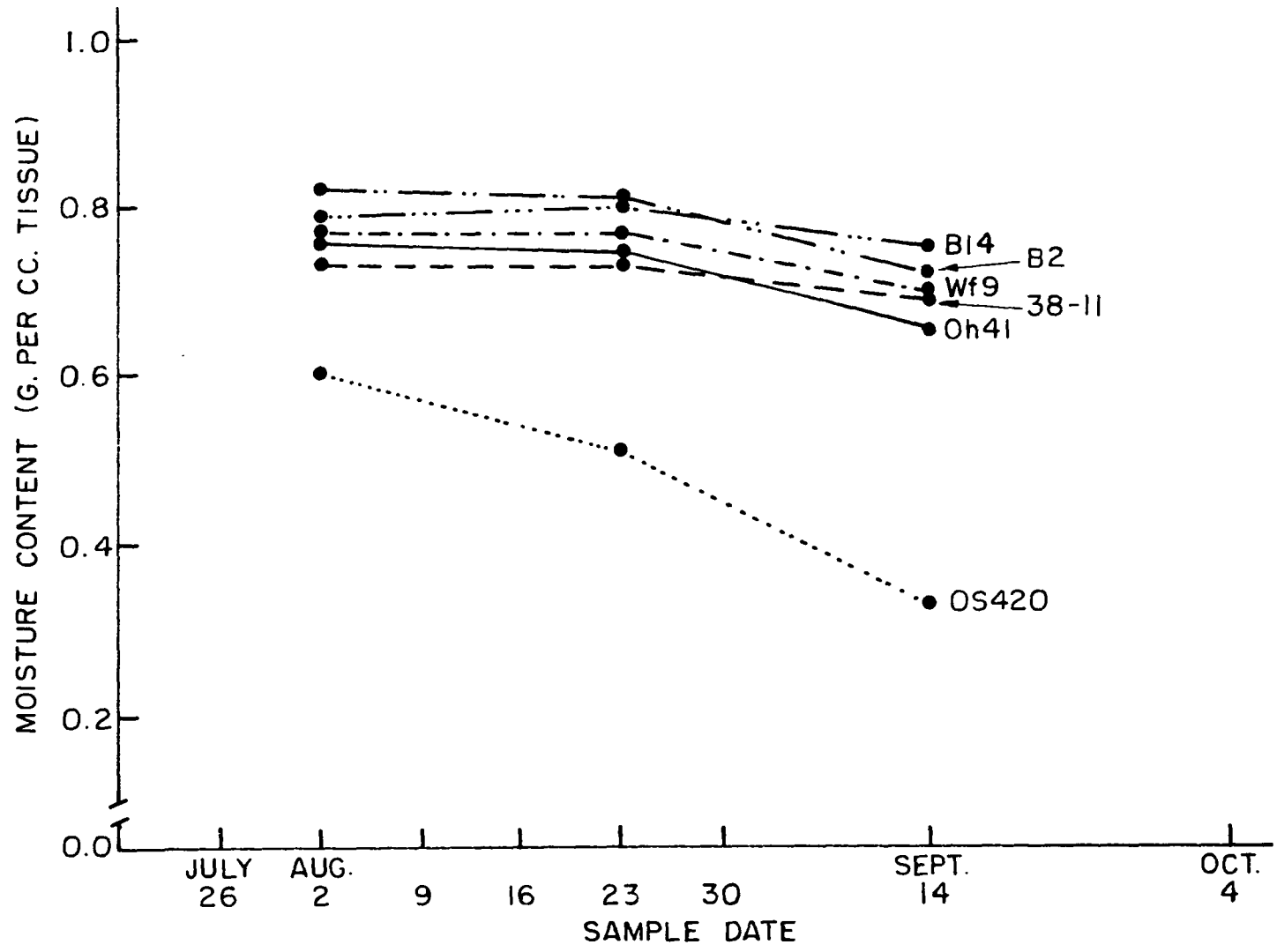

o WHOLE INTERNODE
● PITH CORE
MOISTURE CONTENT (G. PER CC. TISSUE)
1.0
0.8
0.6
0.4
0.2
0.0
1
2
3
4
5
6
STALK ROT RATING

Figure 17. Seasonal trend in field averages of water content measured as grams of water per cc. for whole internode tissue of the six varieties in 1955. Field averages, given in Table 6, were derived from field averages of grams fresh weight per cc. (density) and mg. total dry matter per cc. of whole internode tissue given in Table 15 in the Appendix.


MOISTURE CONTENT (G. PER CC. TISSUE)
1.0
0.8
0.6
0.4
0.2
0.0
B14
B2
Wf9
38-11
Oh41
OS420
JULY 26
AUG. 2
9
16
23
30
SEPT. 14
OCT. 4
SAMPLE DATE

Oh41, the most susceptible of the group, at the bottom. A high correlation existed between the replicate averages of grams of water per cc. of whole internode tissue and stalk rot ratings on September 13, r = 0.88. The replicate data for both on that date are given in Table 7 and shown graphically with the appropriate regression line in Figure 16. It was concluded that water content of whole internodes and especially their pith cores, because of the obvious relation to stalk rot rating groups, was a measure of some physiological condition closely associated with stalk rot resistance. It appeared that water content was an index of the physiological state of the cells, living cells being well hydrated and dead cells being spongy and dry. An attempt to determine the living condition of these tissues using a tetrazolium stain was unsuccessful, and this aspect was studied more thoroughly in 1956.

In comparing whole internode moisture data of 1954 and 1955, it was particularly interesting to make the comparison on a volume basis. There was very good agreement between varieties in both years except for OS420. In the other varieties, seasonal differences on the comparative dates were usually less than 0.05 g. and approached 0.1 g. in a few cases. In OS420, 1955 results were 0.15 g. less than 1954 in early August, 0.18 g. less in late August, and 0.27 g. less per cc. of tissue in mid-September.

Density of the pith cores and whole internodes

Since fresh weight varied among and within varieties with time and was found to be unsuitable as a comparative basis, it was converted to grams fresh weight per cc. of tissue as were other gross physiological measurements. This density data for pith cores and whole internodes are given in Table 15 in the Appendix.

The trends in pith core density, shown in Figure 18, were very similar to those for grams of water per cc. of pith cores. The resistant varieties formed a group high in density beginning on July 26 at about 0.95 to 1.00 density units, continued through August at that general level and dropped sharply from 0.90 in late August to about 0.50 density units in October. The varieties 38-11 and Oh41 started at about 0.60 density units on July 26, and dropped slowly in density throughout the remainder of the experiment. Variety Oh41 dropped to about 0.35 density units in mid-September, and 38-11 reached this level in early October. As with grams of water per cc. of pith core tissue, variety OS420 was lowest in density starting at about 0.50 density units on July 26, decreased slowly to about 0.45 on August 23, and then dropped to about 0.20 on September 14. On September 14, density of pith cores was highly correlated with stalk rot ratings, $r = 0.90$. Field averages of whole internode density, presented graphically in Figure 19, were similar in trends to grams water per cc. of whole internode tissue, variety OS420

Figure 18. Seasonal trend in field averages of grams of fresh weight per cc. (density) for pith core tissue of the six varieties in 1955. Replicate and field averages are given in Table 15 in the Appendix.

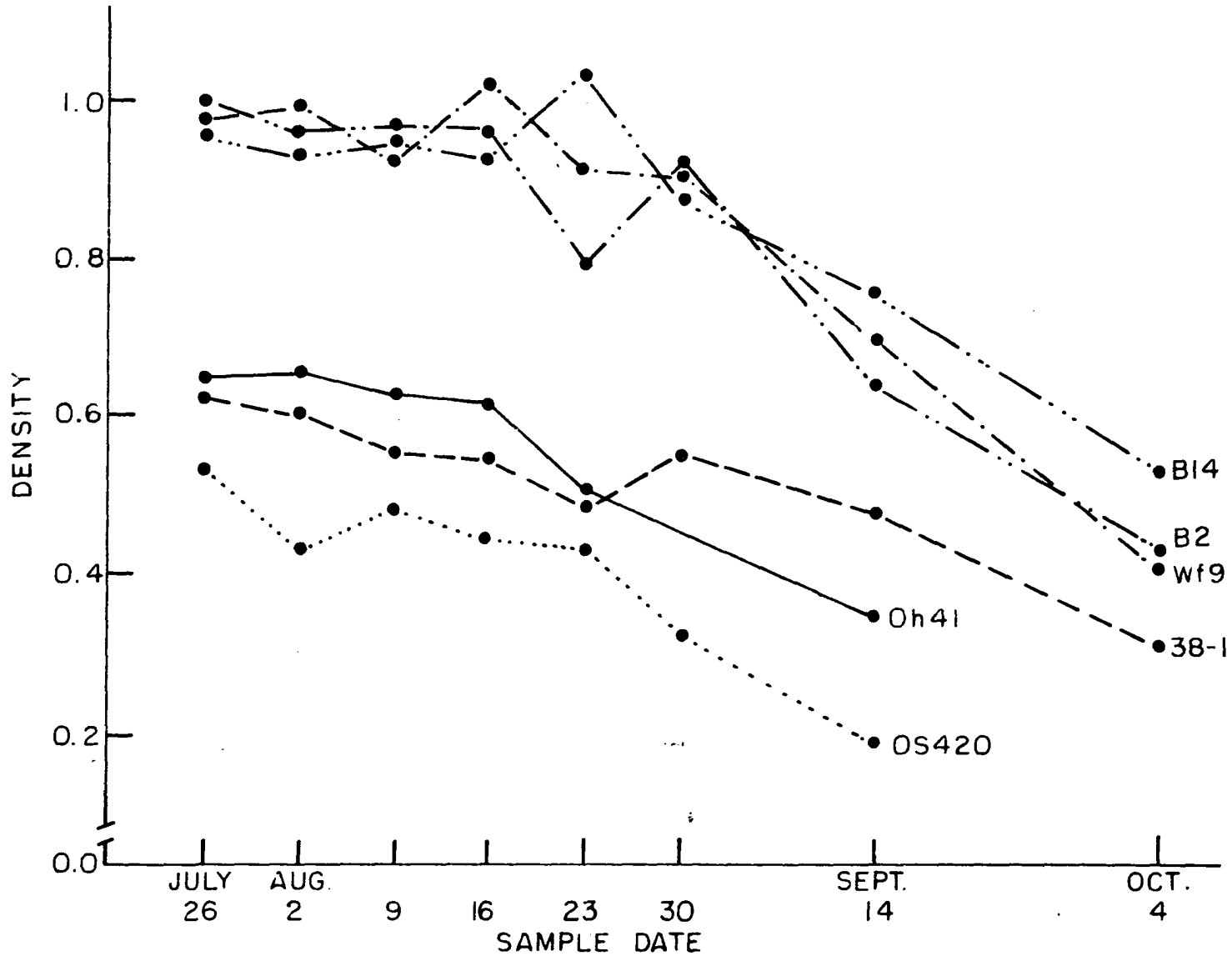
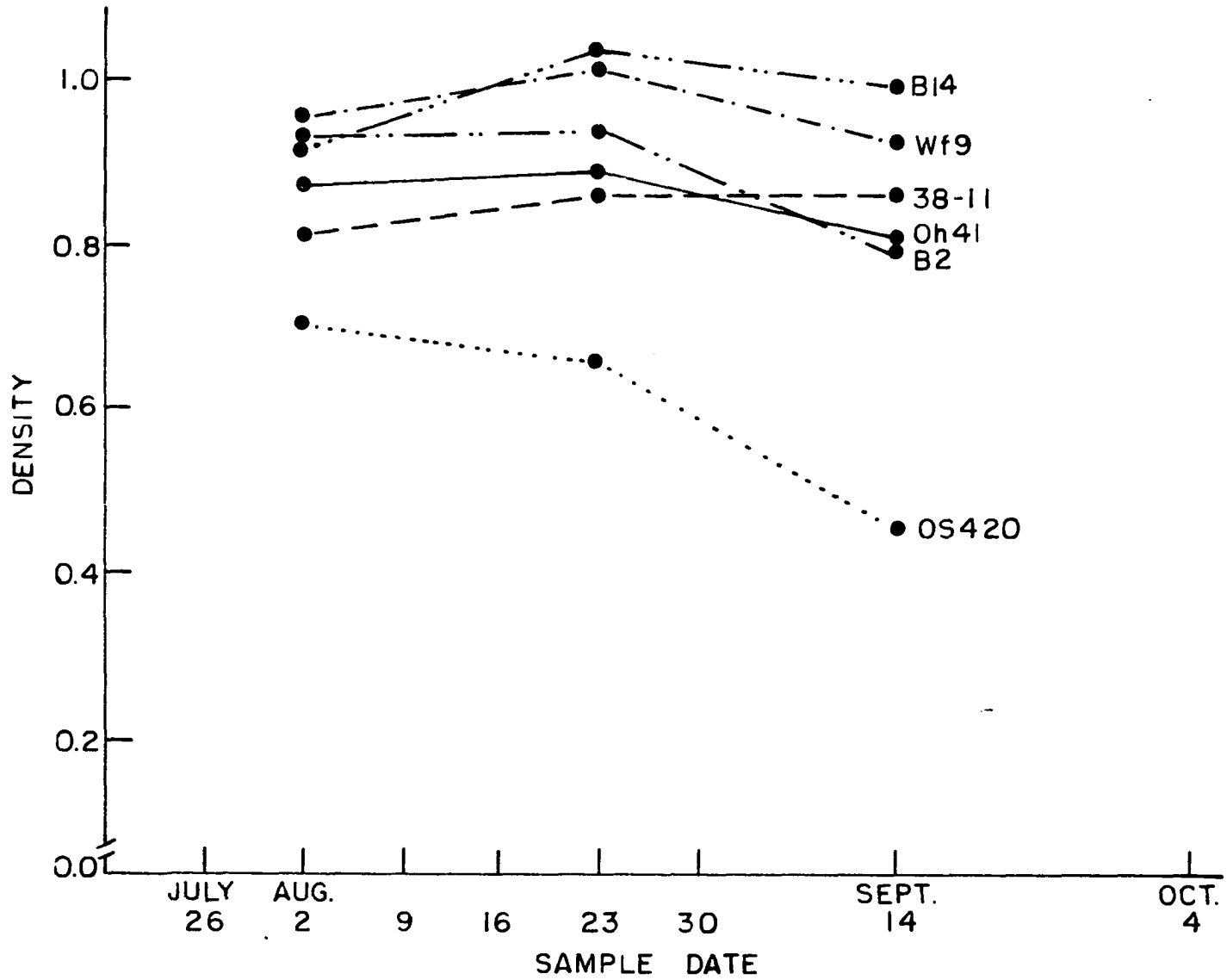

1.0
0.8
0.6
0.4
0.2
0.0
DENSITY
JULY 26
AUG. 2
9
16
23
30
SEPT. 14
OCT. 4
SAMPLE DATE
B14
B2
Wf9
Oh41
38-11
OS420

Figure 19. Seasonal trend in field averages of grams of fresh weight per cc. (density) for whole internode tissue of the six varieties in 1955. Replicate and field averages are given in Table 15 of the Appendix.

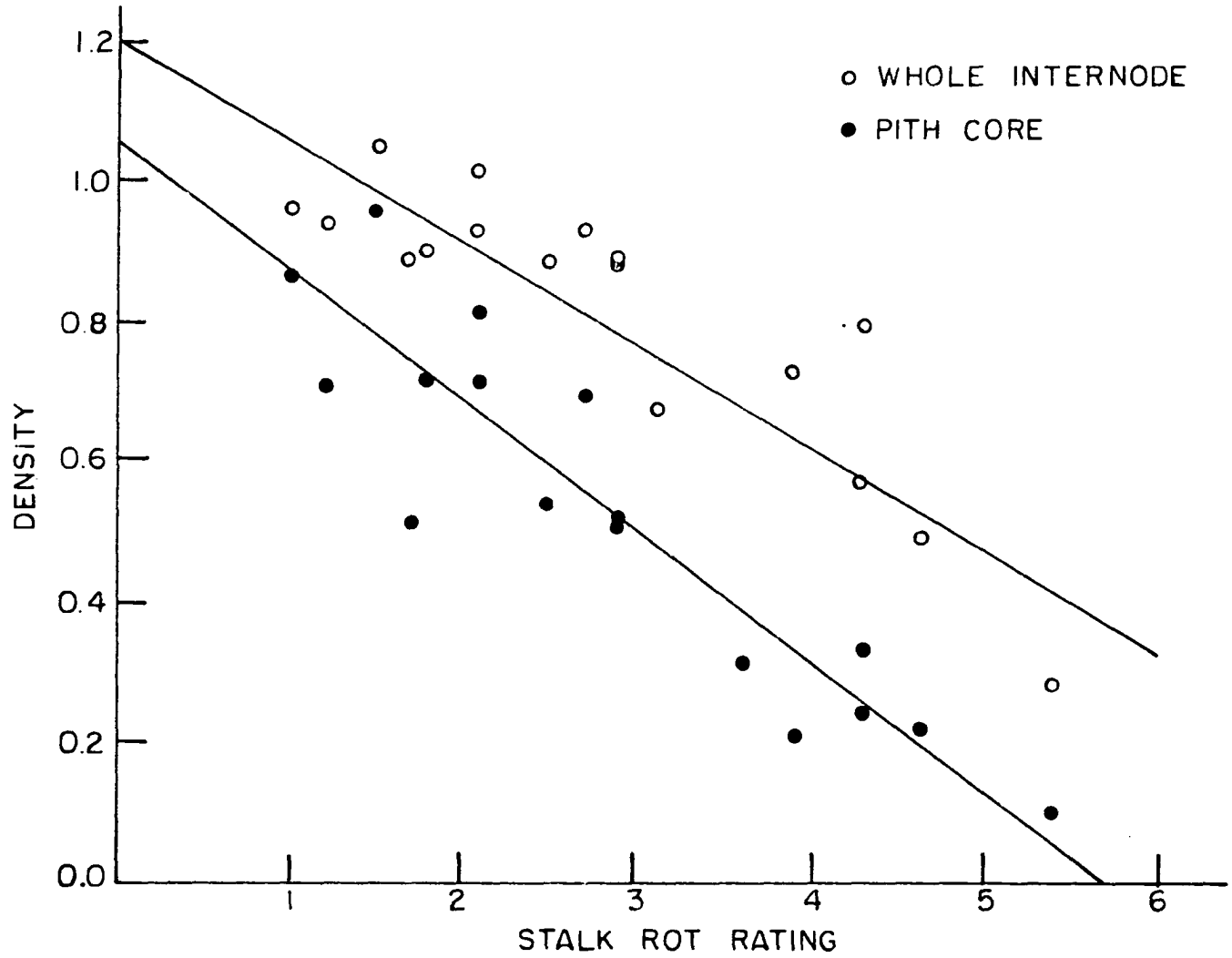

1.0
0.8
0.6
0.4
0.2
0.0
DENSITY
B14
Wf9
38-11
Oh41
B2
OS420
JULY 26
AUG. 2
9
16
23
30
SEPT. 14
OCT. 4
SAMPLE DATE

again being separated from the close grouping of the other five lines studied. The density of the whole internodes also were highly correlated with stalk rot rating, r = 0.87, on the basis of replicate averages. The data for each variety replicate average are given in Table 7, and presented graphically with the appropriate regression line in Figure 20.

Although pith core density and stalk rot rating appeared to be correlated at later dates, no density data were obtained on or near dates of stalk rot ratings other than September 14. As with grams of water per cc. of tissue, high density was associated with resistance and low density with susceptibility. This relationship was studied further in 1956 on a larger number of varieties.

Since pith core density and grams of water were closely related to stalk rot ratings, and since the former measurement required less effort per sample, the relationship between the two indices was determined. There was a high correlation between pith core density and grams of water per cc. of pith core tissue, r = 0.99. It was decided, therefore, that the simplest measure, density, would be used in forthcoming experiments. Whole internode density and grams of water per cc. of whole internode tissue also were highly correlated, r = 0.97. Since pith core data separated the stalk rot rating groups more clearly than did whole internode data, it was decided that pith tissue characteristics were probably more closely related to the factors involved in resistance and the

Figure 20. Relationship between grams of fresh weight per cc. (density) of whole internode and pith core tissue and stalk rot ratings for the six varieties on September 14, 1955. Each point represents the replicate average for these measurements given in Table 7.


o WHOLE INTERNODE
● PITH CORE
DENSITY
1.2
1.0
0.8
0.6
0.4
0.2
0.0
1
2
3
4
5
6
STALK ROT RATING

study of this tissue would be emphasized in 1956.

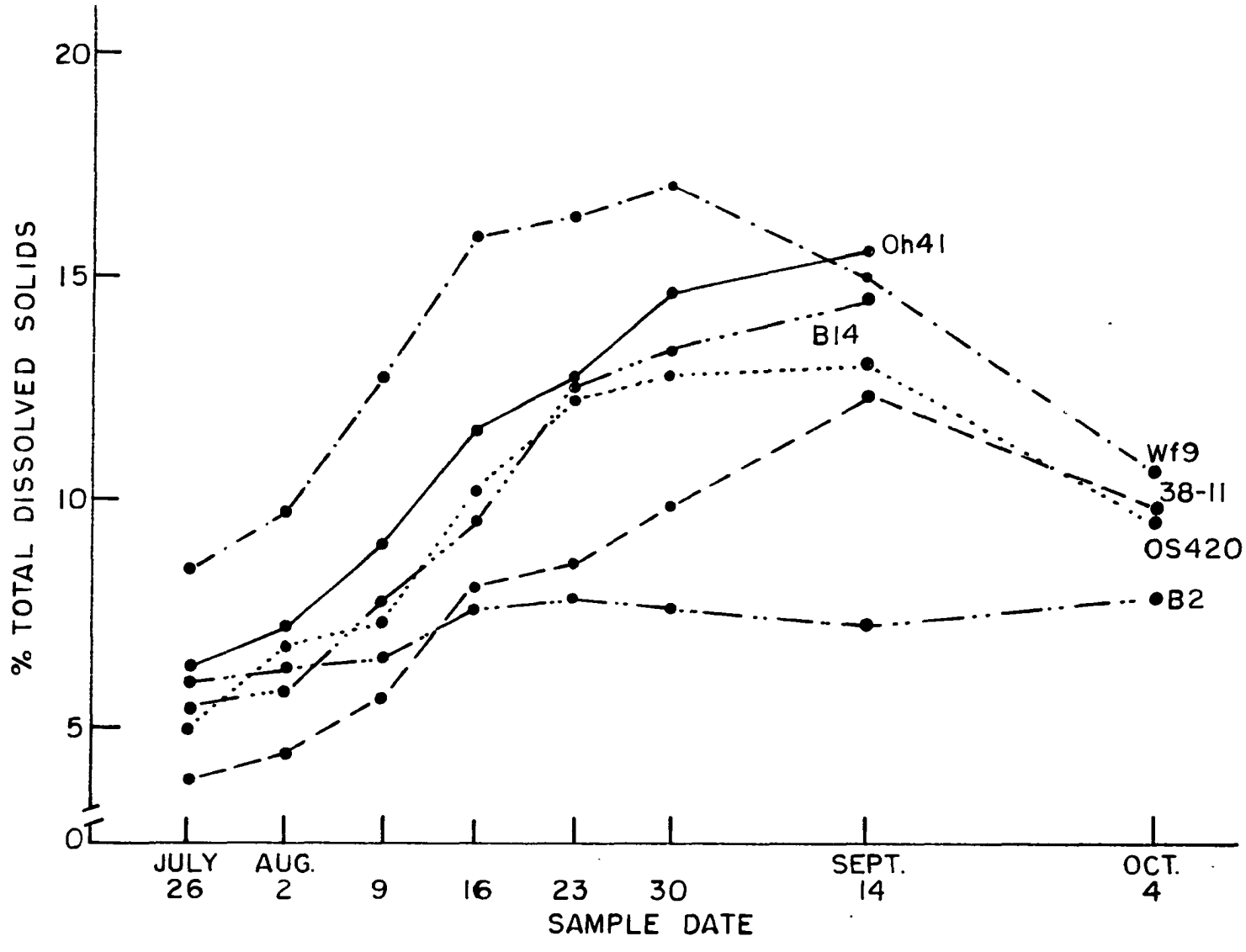
Recalculation of 1954 data to yield density information also showed good agreement between 1954 and 1955 results for all dates and varieties except variety OS420 which was 0.2 to 0.3 density units below 1954 results in 1955. The mid-September density of variety Oh41 and B2 was about 0.1 density units below mid-September data of 1954. In general, the differences between 1955 and 1954 were less than 0.05 density units.

Total dissolved solids

Data for the percentage total dissolved solids in whole first internodes are given in Table 15 in the Appendix and presented graphically in Figure 21. These data were used to calculate mg. of total dissolved solids per cc. of whole internode and pith core tissue in a manner similar to 1954. It was assumed that the percentage total dissolved solids would be uniform throughout the internode tissue.

Variety Wf9 was highest in per cent total dissolved solids throughout the season, peaking about five weeks after silking. Varieties B14, OS420, Oh41, and 38-11 were similar in trend but lower in magnitude than Wf9. Varieties B14 and 38-11 dropped in level after peaking on September 14 about five to six weeks after silking. Variety B2 gained very little throughout the season and was lowest in per cent total dissolved solids after mid-August.

Figure 21. Seasonal trend in field averages of per cent total dissolved solids of expressed stalk sap for first internode tissue of the six varieties in 1955. Replicate and field averages are given in Table 15 in the Appendix.


20
15
10
5
0
% TOTAL DISSOLVED SOLIDS
Oh41
B14
Wf9
38-11
OS420
B2
JULY 26
AUG. 2
9
16
23
30
SEPT. 14
OCT. 4
SAMPLE DATE

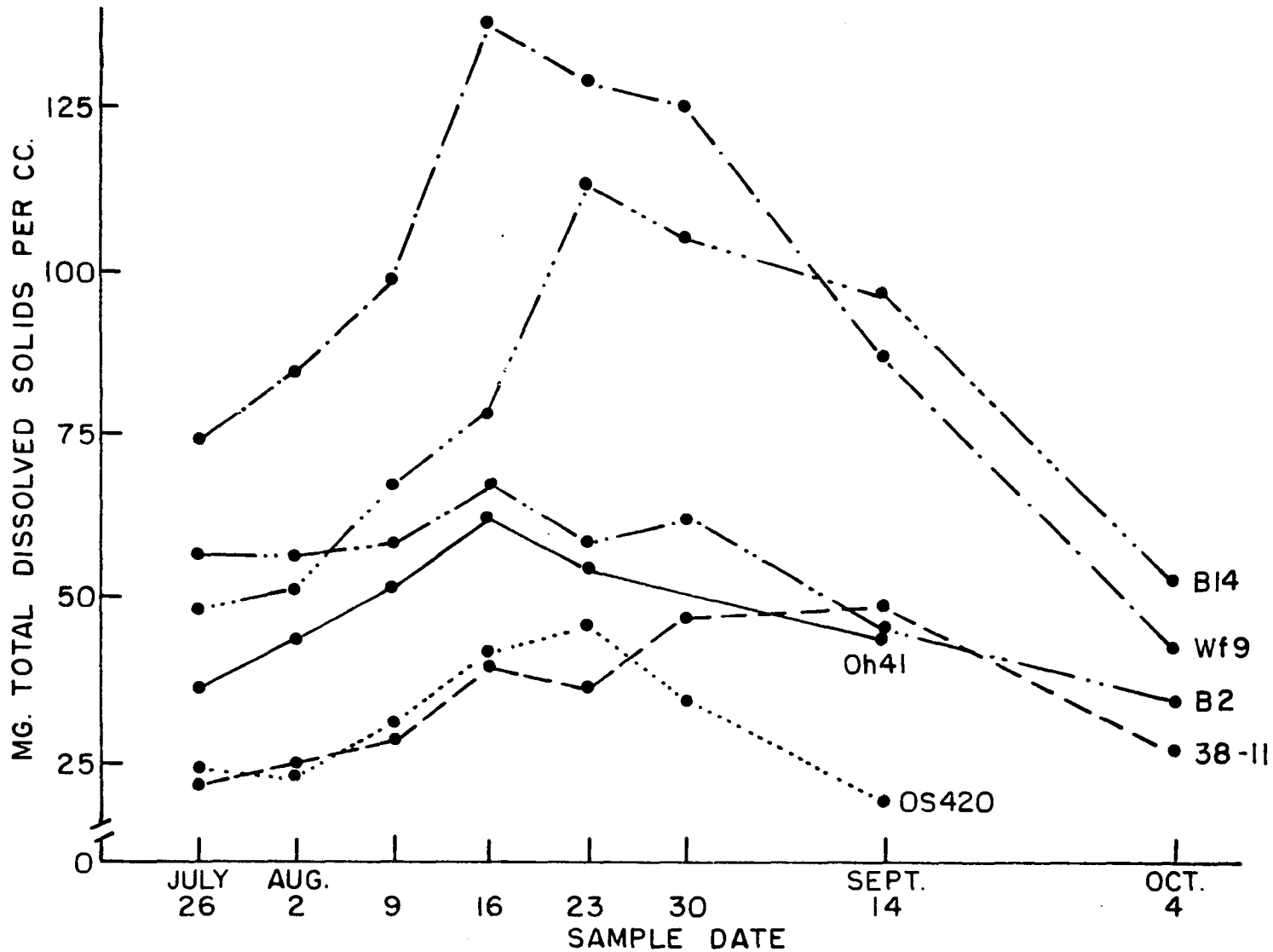
In general, trends in per cent total dissolved solids were not in good agreement with 1954 trends. Variety B2 peaked high in September of 1954 and was low in 1955. Varieties Oh41, OS420, and Wf9 had peaked by late August of 1954 but were increasing in this period in 1955. As in 1954, there was no apparent relationship between per cent total dissolved solids and stalk rot ratings.

The changes with time in percentages of total dissolved solids and actual weights of total dissolved solids differed greatly and points out the superiority of the latter basis. The data for mg. per cc. of pith core tissue are given in Table 15, in the Appendix and shown graphically in Figure 22.

Variety Wf9 increased rapidly in mg. of total dissolved solids per cc. of pith tissue, peaking sharply on August 16 and dropped off sharply after August 30. Variety B14 followed a similar trend peaking sharply on August 23. Varieties Oh41 and B2 peaked on August 16 and declined slowly after that date. Varieties 38-11 and OS420 were lowest to August 23 at which time OS420 peaked and decreased to its starting level by mid-September. Variety 38-11 continued to increase and reached a plateau in early September then decreased. The peaks and differences in trends of these varieties were not indicated by percentage data.

On September 14, Wf9 and B14 contained about 90 mg. of total dissolved solids per cc. of pith core; 38-11, Oh41, and B2 contained about 45 mg., and OS420 contained about 20 mg.

Figure 22. Seasonal trend in field averages of mg. total dissolved solids per cc. for pith core tissue of the six varieties in 1955. Replicate and field averages are given in Table 15 in the Appendix.

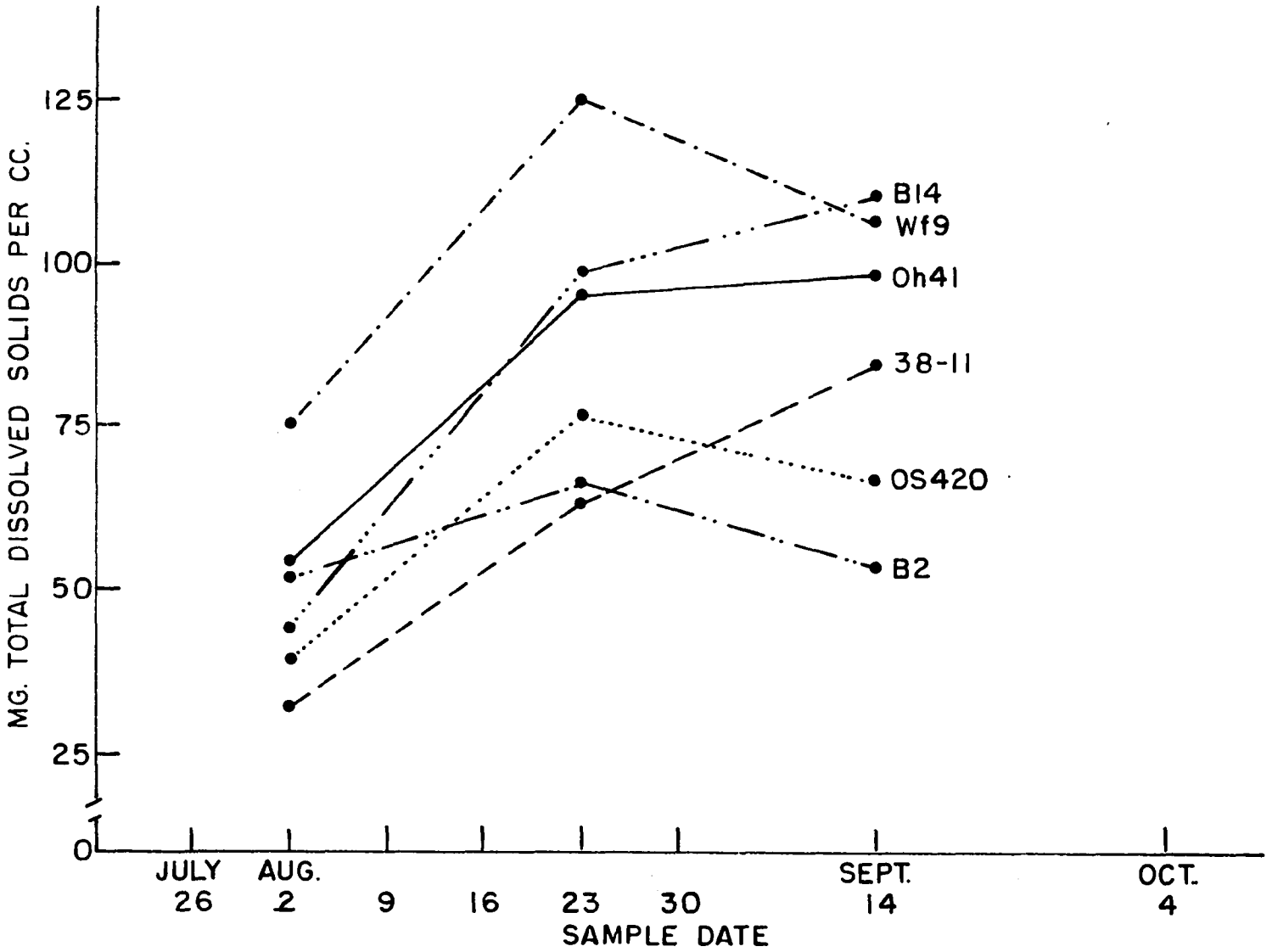

MG. TOTAL DISSOLVED SOLIDS PER CC.
125
100
75
50
25
0
JULY 26
AUG. 2
9
16
23
30
SEPT. 14
OCT. 4
SAMPLE DATE
B14
Wf9
Oh41
B2
38-11
OS420

per cc. of tissue. Had B2 been as high as Wf9 and B14, an orderly arrangement from resistant to susceptible varieties would have evolved. Since this was not the case, no clear relationship existed between mg. total dissolved solids per cc. of pith tissue and stalk rot ratings.

Whole internode data for mg. total dissolved solids per cc. of tissue are given in Table 15 in the Appendix and presented graphically in Figure 23. In the plants of B2, Wf9, and B14, the amount of total dissolved solids contained per cc. of whole internode tissue was comparable to the levels found in their pith core tissue. In the susceptible varieties, the whole internodes contained greater amounts than did their pith cores, especially at later dates. This is probably attributable to the decrease in water content occurring in pith core tissue in these varieties. As with pith cores, no relation between mg. total dissolved solids per cc. of whole internode tissue and stalk rot ratings was apparent.

A comparison of 1954 and 1955 whole internode total dissolved solids per cc. data shows wide difference in variety trends in the two years. In 1955, variety B2 was consistently lower throughout the comparable period, containing about half the amounts found in 1954 at late August and mid-September dates. Although 1955 early August data for OS420 are lower than that in 1954, later dates for this variety in the two years are comparable. Varieties 38-11, B14, Oh41, and Wf9 were equally below their 1954 results in 1955 in early August, but

Figure 23. Seasonal trend in field averages of mg. total dissolved solids per cc. for whole internode tissue of the six varieties in 1955. Replicate and field averages are given in Table 15 in the Appendix.


MG. TOTAL DISSOLVED SOLIDS PER CC.
125
100
75
50
25
0
B14
Wf9
Oh41
38-11
OS420
B2
JULY
26
AUG.
2
9
16
23
30
SEPT.
14
OCT.
4
SAMPLE DATE

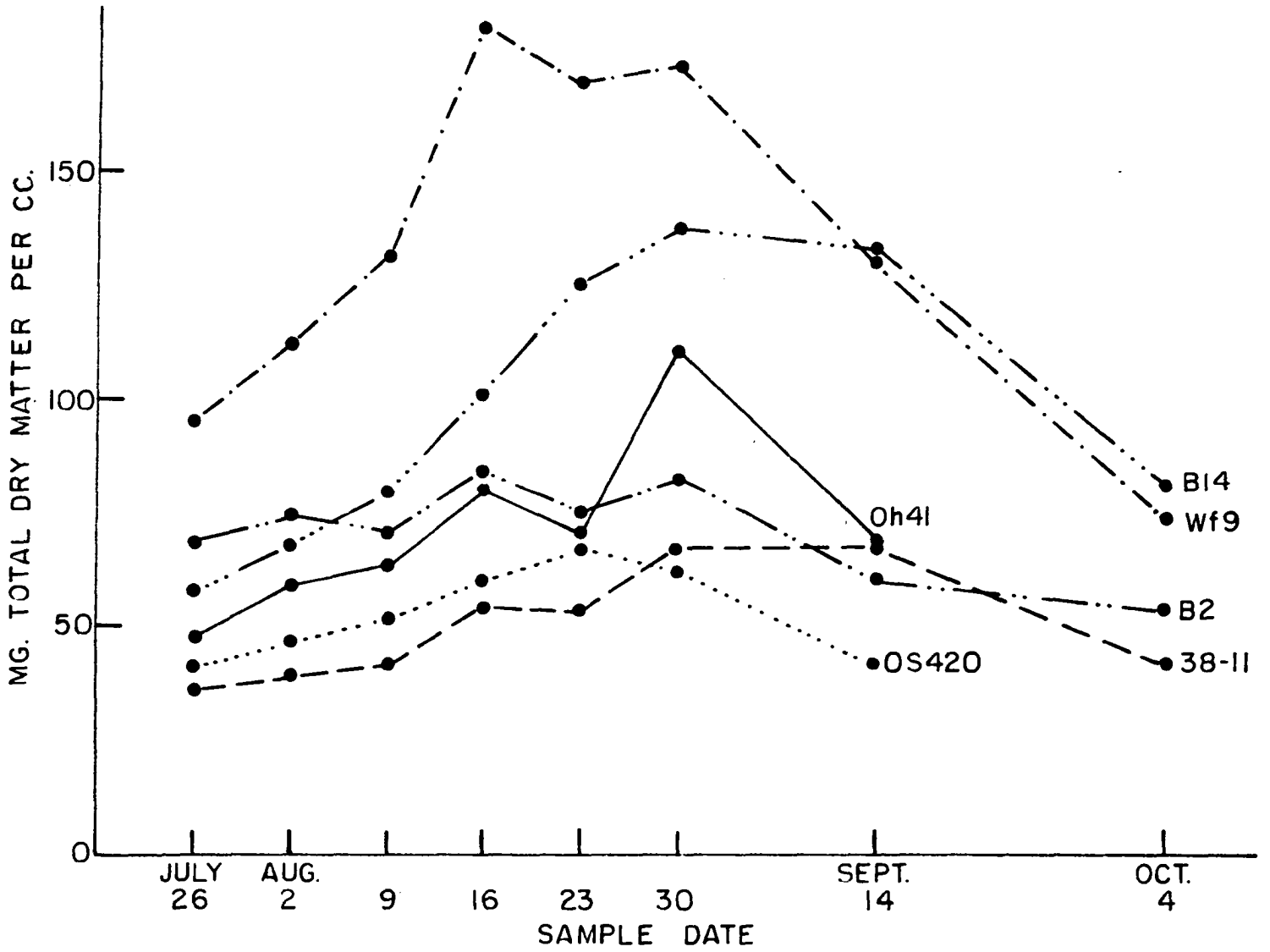
by mid-September these varieties were considerably above the 1954 normal plant content and were in fact comparable to the defruited plant results in 1954. This may be a reflection of barren plants and poor ear set in 1955. Since no apparent correlation existed between these measurements and stalk rot ratings in either year, this measure was considered to be a poor index of stalk rot ratings.

Total dry matter per unit volume

Data for total dry matter per cc. of whole internode and pith core tissue is given in Table 15 in the Appendix, Trends and peaks in mg. total dry matter per cc. of pith core, shown in Figure 24, follow those of mg. of total dissolved solids per cc. of pith core tissue in Figure 22. Variety Wf9 peaked on August 16, maintained this high level until August 30, and then decreased to its starting level by October 4. Variety B14 followed a similar trend, peaking in late August and decreasing after September 14. All other varieties increased in total dry matter slowly through August and then decreased slowly in September. On September Wf9 and B 14 contained about 130 mg. of total dry weight per cc. of pith core tissue; Oh41, B2, and 38-11 contained about 55 mg., and OS420 contained about 45 mg. per cc. of pith core tissue. Had variety B2 been high in total dry matter content, an orderly arrangement from resistant to susceptible varieties would have evolved.

The data for mg. total dry matter per cc. of whole inter-

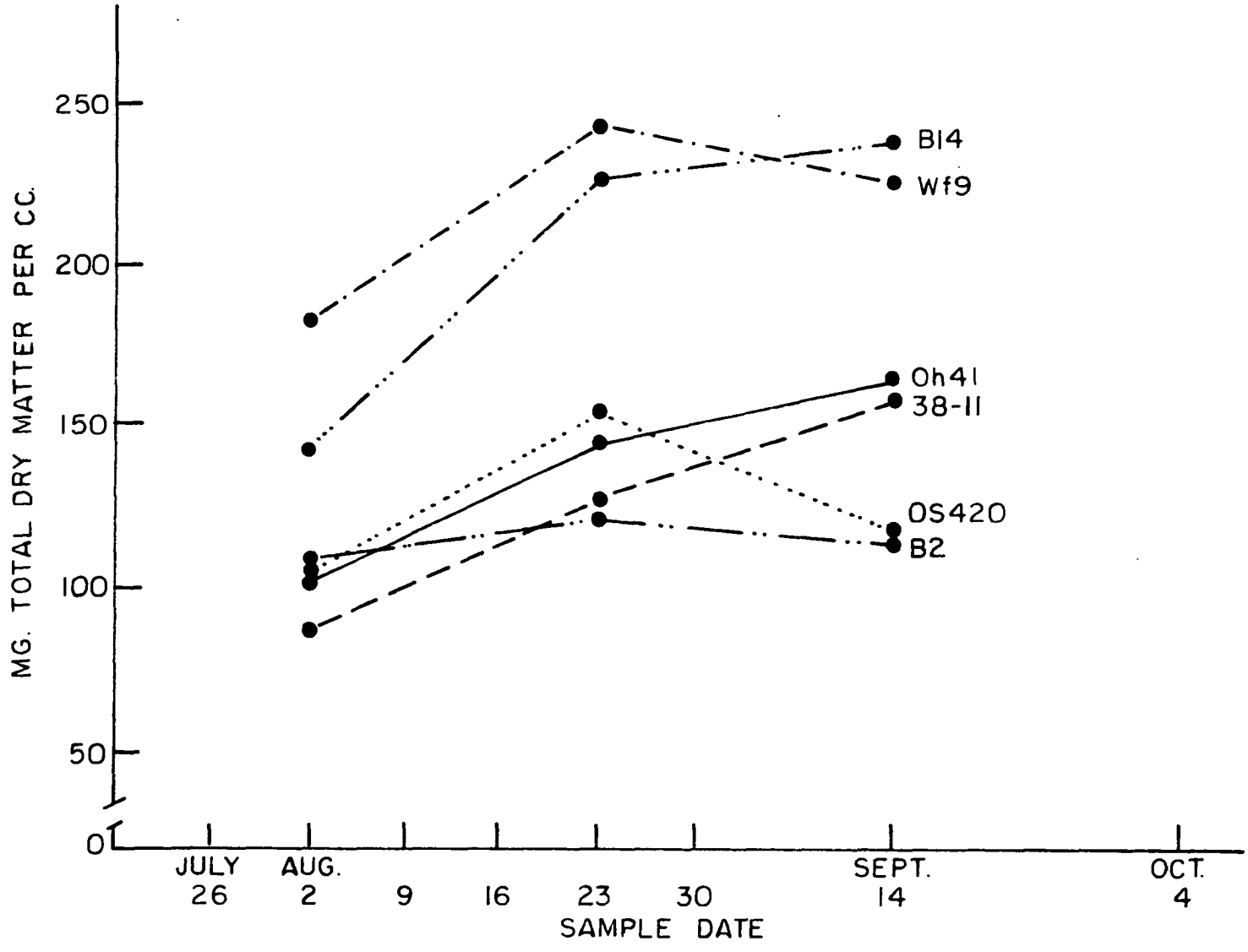
Figure 24. Seasonal trend in field averages of mg. total dry matter per cc. for pith core tissue of the six varieties in 1955. Replicate and field averages are given in Table 15 in the Appendix.


MG. TOTAL DRY MATTER PER CC.
150
100
50
0
JULY 26
AUG. 2
9
16
23
30
SEPT. 14
OCT. 4
SAMPLE DATE
B14
Wf9
Oh41
B2
OS420
38-11

node tissue are presented graphically in Figure 25. Varieties Wf9 and B14 followed similar trends and clearly were highest throughout the period of measurement. The remaining varieties began at a lower level in early August and increased from August 2 to August 23. On the latter date, variety OS420 dropped to approximately its starting level by September 14. Variety B2 did not peak as sharply as OS420 but decreased to an equivalent level on September 14. Varieties Oh41 and 38-11 continued to increase in total dry matter from August 23 to September 14. At the latter date varieties B14 and Wf9 contained about 230 mg. total dry matter per cc. of tissue, Oh41 and 38-11 contained about 160 mg., and OS420 and B2 contained about 115 mg. per cc. of tissue. These levels were considerably higher in whole internodes than in pith cores and indicate the effect of the outer pith and rind on this index. As before, had B2 been in the high group, an orderly arrangement of resistant to susceptible varieties would have evolved. Since this was not the case, no relationship between total dry matter of whole internodes or their pith cores and stalk rot ratings was apparent.

Comparison of 1954 and 1955 whole internode data shows all varieties in 1955 were below the 1954 measurement in early August. By late August variety B2 was considerably below 1954 results while 38-11, OS420, and B14 compared well with 1954 results at this period and Wf9 and Oh41 in 1955 had increased above the 1954 level for normal plants at this date. In mid-

Figure 25. Seasonal trend in field averages of mg. total dry matter per cc. for whole internode tissue of the six varieties in 1955. Replicate and field averages are given in Table 15 in the Appendix.


MG. TOTAL DRY MATTER PER CC.
250
200
150
100
50
0
B14
Wf9
Oh41
38-11
OS420
B2
JULY
26
AUG.
2
9
16
23
30
SEPT.
14
OCT.
4
SAMPLE DATE

September, B2 was still considerably below 1954 results for normal plants, variety OS420 was slightly below 1954 results, varieties 38-11, Wf9, and B14 were about equal to 1954 results of normal plants and Oh41 in 1955 was considerably above the 1954 results of normal plants. No agreement between the general increase in susceptibility of these varieties in 1955 and the trends of the two years are apparent. It is concluded that total dry matter per cc. of pith core or whole internode tissue is not a good index of resistance.

Insoluble dry matter per unit volume

This data, obtained as in 1954, is given in Table 8 and presented graphically in Figures 26 and 27 for pith core and whole internode tissue, respectively. The mg. of insoluble dry matter per cc. of pith core tissue of variety Wf9 increased sharply from July 26 to August 16 and decreased slowly through the remainder of the experiment after that date. Variety B14 followed a similar trend at a lower level but peaked on September 14 and decreased slowly to October 4. What components of the insoluble dry matter were lost after these peaks is not known. The two varieties discussed were higher in insoluble dry matter in September and October than the other four varieties. The latter four increased slowly to mid-September and maintained that level to October 4.

In whole internode data, presented in Figure 27, Wf9 and B14 are clearly higher from August 2 to September 14 than the four varieties which were low and closely grouped. In both

Table 8. Field average for mg. insoluble dry matter per cc. of whole first internode (W) and pith core (P) tissue in 1955

Variety		Sample date							
		July 26	Aug. 2	Aug. 9	Aug. 16	Aug. 23	Aug. 30	Sept. 14	Oct. 4
Wf9	P	22	28	33	50	40	47	42	31
	W	--	107	--	--	118	--	122	--
38-11	P	13	14	13	15	17	19	18	15
	W	--	56	--	--	64	--	74	--
Oh41	P	13	16	12	16	16	--	23	--
	W	--	49	--	--	50	--	65	--
OS420	P	18	22	21	20	21	27	24	--
	W	--	64	--	--	77	--	76	--
B2	P	12	15	11	17	16	21	17	20
	W	--	55	--	--	59	--	62	--
B14	P	10	16	11	23	20	32	35	27
	W	--	98	--	--	126	--	127	--

pith core and whole internodes of all varieties no apparent correlation existed between insoluble dry matter per cc. of tissue and stalk rot ratings. This suggests that morphological resistance based on cell wall thickness or other structural components is not an important factor since the rate of increase in susceptibility did not correspond to any observable changes or differences in these measurements. This suggestion is supported by the fact that in 1955 the plants were more susceptible even though whole internode results for insoluble

Figure 26. Seasonal trend in field averages of mg. insoluble dry matter per cc. of pith core tissue of the six varieties in 1955. Field averages, given in Table 8, were derived from field averages of mg. total dissolved solids per cc. and mg. total dry matter per cc. of pith core tissue given in Table 15 in the Appendix.

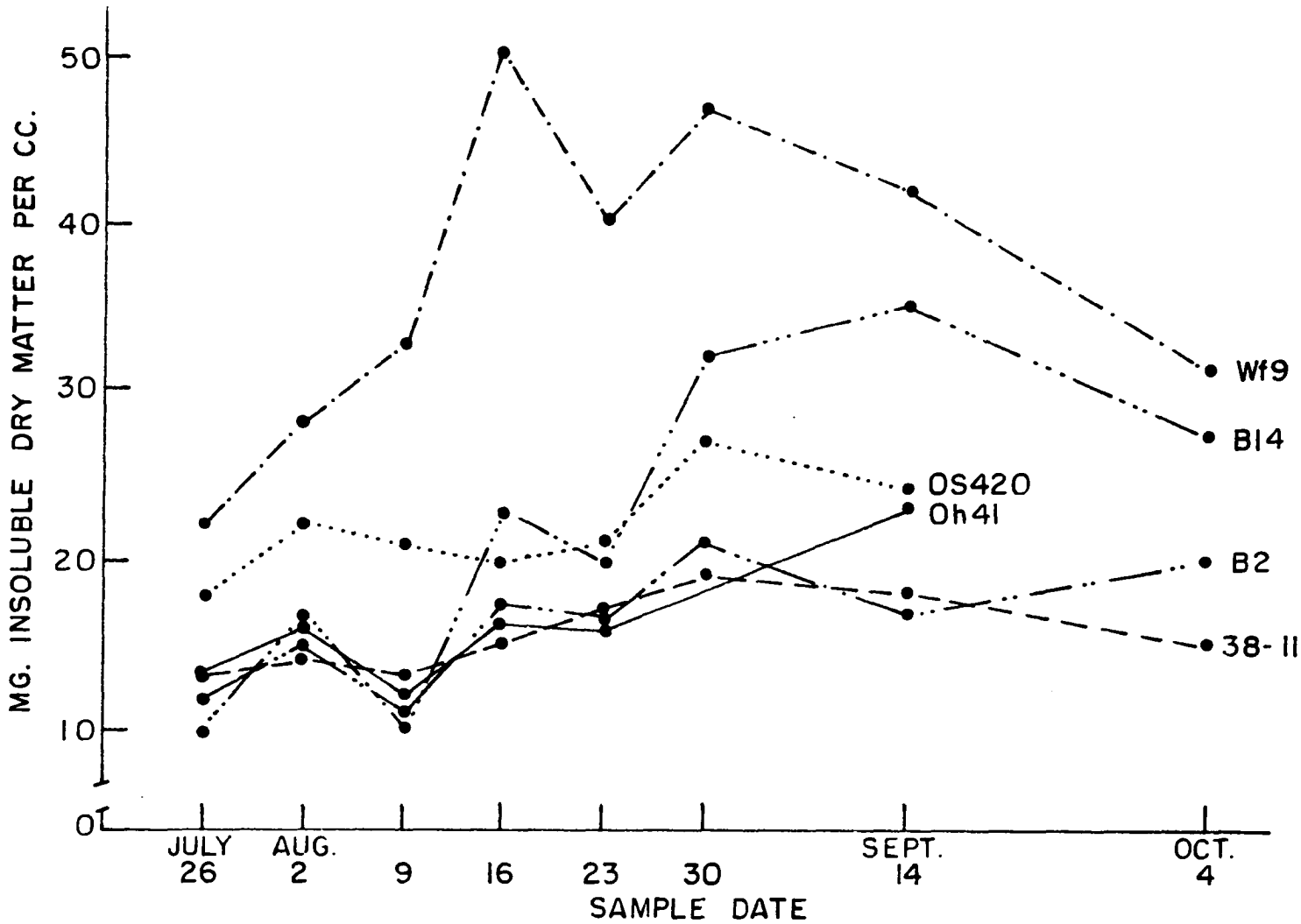
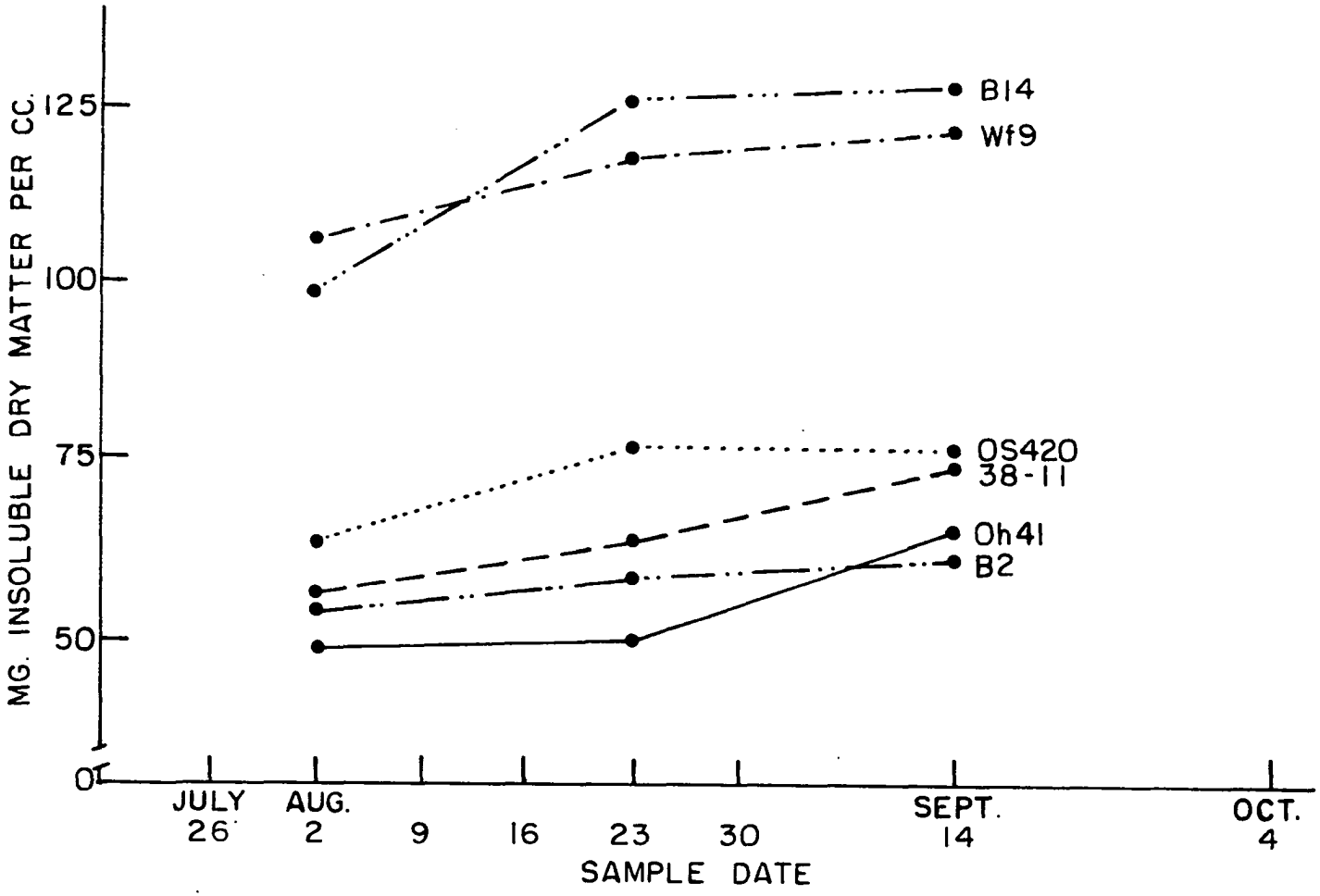

MG. INSOLUBLE DRY MATTER PER CC.
50
40
30
20
10
0
JULY 26
AUG. 2
9
16
23
30
SEPT. 14
OCT. 4
SAMPLE DATE
Wf9
B14
OS420
Oh41
B2
38-11

Figure 27. Seasonal trend in field averages of mg. insoluble dry matter per cc. of whole internode tissue of the six varieties in 1955. Field averages, given in Table 8, were derived from field averages of mg. total dissolved solids per cc. and mg. total dry matter per cc. of whole internode tissue given in Table 15 in the Appendix.


MG. INSOLUBLE DRY MATTER PER CC.
125
100
75
50
0
B14
Wf9
OS420
38-11
Oh41
B2
JULY 26
AUG. 2
9
16
23
30
SEPT. 14
OCT. 4
SAMPLE DATE

dry matter were higher than for normal plants in 1954.

On the basis of the 1955 results, it was felt that the resistance to spread of the organism was probably not morphological, but involved a physiological mechanism related in some way to decrease in water content and density and to pith condition changes during the growth of the plants.

Experimental Results - 1956

In 1954 and 1955, the study of gross physiological and morphological differences yielded the fact that some change in pith condition probably associated with the changes in water content and density of the tissue were closely related to disease response measured by extent of tissue discoloration following inoculation. The purpose of the 1956 study was to extend these investigations to a larger number of varieties to determine to what extent these relationships held. Twenty varieties, 14 inbreds and 6 single crosses, were selected for this purpose with the aid of Dr. W. A. Russell. The six inbred varieties previously studied were included. Since the upper internodes of the stalk had been shown to be more susceptible than the lower internodes, this aspect was more fully investigated with the possibility that future studies of the mechanism of resistance could then be undertaken in the same plant. This approach would eliminate experimental errors due to differences in varieties and plant

conditions and permit intensified research leading to a better understanding of resistance with a very limited but highly selected group of plants. Since density and grams of water per cc. of tissue were highly correlated in 1955, only density measurements were made in this year's study. Three factors then were important, density, pith condition, and stalk rot ratings. The pith core technique was used in preference to the whole internodes since the stalk rot rating groups were clearly separated by the former in 1955. All other measurements made in 1954 and 1955 were discontinued. It was felt that these could best be studied further only following a better understanding of the resistance mechanism for their relationship to resistance was not clear. An attempt also was made to characterize the condition of the pith and its relationship to spread of the organism in terms of living and dead tissue.

The dates of silking for each variety are given for each replicate in Table 16 in the Appendix. Dates of silking in replicates three and four were not readily obtained in some varieties due to the small ear size and stunting of plants. Varieties Wf9, 38-11, B2, and OS420 were markedly stunted in the fourth replication, and a large number of plants of B2 were barren in that replication.

Stalk rot and pith condition ratings

On September 6, stalk rot ratings were made on the 20

varieties inoculated August 7 in the first and fourth internodes above the uppermost brace roots. The replicate and field averages of these ratings are given in Table 9. Pith condition ratings were taken on September 6, and the replicate and field averages of these ratings also are given in Table 9 for first and fourth internodes. Each replicate average is the mean of a maximum of ten plants.

In every case, 72 in all, where first and fourth internodes were rated for stalk rot following inoculation or for pith condition, the rating of the fourth internode was equal to or greater than the rating of the first internode. Stalk rot ratings and pith condition ratings in variety B2 showed this variety to be resistant in both positions tested. Most of the varieties were resistant or tended to be resistant in the lower stalk position but tended to be or were susceptible in the upper internode. The pith condition and stalk rot ratings made on September 6 were highly correlated, $r = 0.90$. In 1955, a similar experiment in first and fourth internodes gave an r value of 0.89. The data in Table 9 concerning these measurements also are presented graphically in Figure 28 with the appropriate regression line. As in 1955, all 5 and 6 stalk rot ratings were considered to be 4 for the correlation analysis. The data for both stalk positions were pooled for the analysis. It was concluded that some characteristic of pith condition was closely related to the mechanism of resistance to spread of the organism. Since both the stalk

Table 9. Replicate and field average of stalk rot rating, pith condition rating and pith core tissue density of first and fourth internodes on September 6, 1956. Replicate averages are based on three stalk samples for density and ten stalk samples for stalk rot and pith condition rating. Plants rated for stalk rot were inoculated August 7. (First internode = 1st, fourth internode = 4th)

Variety and treatment	Replicate 1	2	3	4	Field average
Ia 153 1st					
Pith core density	0.17	0.12	0.24	0.17	0.18
Stalk rot rating	5.8	6.0	5.4	3.5	5.2
Pith cond. rating	4.0	4.0	4.0	3.9	4.0
Oh29 1st					
Pith core density	0.57	0.69	0.62	0.68	0.64
Stalk rot rating	2.3	2.1	1.2	1.5	1.8
Pith cond. rating	2.6	2.7	1.8	1.6	2.2
4th					
Pith core density	0.36	0.38	0.52	0.37	0.41
Stalk rot rating	3.2	3.2	2.6	1.5	2.6
Pith cond. rating	4.0	3.9	3.9	3.5	3.8
M14 1st					
Pith core density	0.91	0.90	0.93	0.90	0.91
Stalk rot rating	2.4	2.1	1.1	1.2	1.7
Pith cond. rating	2.1	1.7	1.0	1.3	1.5
4th					
Pith core density	0.48	0.45	0.56	0.42	0.48
Stalk rot rating	3.7	4.1	3.2	3.4	3.7
Pith cond. rating	3.7	4.0	4.0	3.2	3.7
R101 1st					
Pith core density	0.95	0.98	1.01	0.98	0.98
Stalk rot rating	1.0	1.0	1.1	1.0	1.0
Pith cond. rating	1.2	1.0	1.3	1.0	1.1
4th					
Pith core density	0.68	0.58	0.55	0.61	0.61
Stalk rot rating	3.1	3.1	3.6	2.2	3.0
Pith cond. rating	2.7	3.8	4.0	2.0	3.1

Table 9. (Continued)

Variety and treatment	Replicate 1	2	3	4	Field average
W22R 1st					
Pith core density	0.66	0.73	0.85	0.73	0.74
Stalk rot rating	2.6	2.5	1.7	1.8	2.3
Pith cond. rating	2.5	2.7	1.9	1.8	2.2
4th					
Pith core density	0.39	0.36	0.35	0.41	0.38
Stalk rot rating	4.1	3.7	2.7	2.6	3.3
Pith cond. rating	4.0	4.0	3.6	3.6	3.8
B2 1st					
Pith core density	1.02	1.01	1.02	1.00	1.01
Stalk rot rating	1.0	1.0	1.0	1.0	1.0
Pith cond. rating	1.0	1.0	1.0	1.0	1.0
4th					
Pith core density	0.98	0.99	1.01	0.98	0.99
Stalk rot rating	1.1	1.0	1.0	1.0	1.0
Pith cond. rating	1.2	1.0	1.0	1.0	1.1
B14 1st					
Pith core density	0.98	1.02	1.02	1.01	1.01
Stalk rot rating	1.1	1.0	1.0	1.0	1.0
Pith cond. rating	1.0	1.0	1.0	1.0	1.0
4th					
Pith core density	0.47	0.53	0.76	0.72	0.62
Stalk rot rating	3.4	3.7	----	----	3.6
Pith cond. rating	3.3	4.0	----	----	3.7
W17RB 1st					
Pith core density	0.80	0.93	0.84	0.86	0.86
Stalk rot rating	3.1	1.1	1.4	1.1	1.7
Pith cond. rating	2.0	1.8	1.2	1.5	1.6
4th					
Pith core density	0.38	0.41	0.57	0.56	0.48
Stalk rot rating	4.0	3.5	2.8	1.6	3.0
Pith cond. rating	3.7	4.0	3.8	3.4	3.7
Wf9 x 38-11 1st					
Pith core density	0.57	0.81	0.94	0.77	0.77
Stalk rot rating	1.6	1.4	1.1	1.1	1.3
Pith cond. rating	1.7	1.2	1.2	1.1	1.3

Table 9. (Continued)

Variety and treatment	Replicate 1	2	3	4	Field average
4th					
Pith core density	0.27	0.31	0.58	0.46	0.41
Stalk rot rating	4.0	3.9	2.2	2.7	3.2
Pith cond. rating	4.0	4.0	3.1	3.5	3.7
Wf9 x M14 1st					
Pith core density	0.78	0.76	0.71	0.94	0.80
Stalk rot rating	2.0	1.2	1.0	1.2	1.3
Pith cond. rating	1.6	1.2	1.3	1.1	1.3
4th					
Pith core density	0.27	0.30	0.30	0.68	0.39
Stalk rot rating	4.7	4.0	2.9	1.4	3.3
Pith cond. rating	4.0	4.0	4.0	3.1	3.8
C131 x B14 1st					
Pith core density	0.85	0.83	0.87	0.98	0.88
Stalk rot rating	2.1	1.2	1.3	1.0	1.4
Pith cond. rating	2.4	1.6	1.2	1.0	1.6
4th					
Pith core density	0.34	0.26	0.33	0.45	0.35
Stalk rot rating	4.6	4.0	2.9	2.7	3.6
Pith cond. rating	4.0	4.0	3.7	3.3	3.8
Wf9 x B14 1st					
Pith core density	0.93	0.92	0.91	0.93	0.92
Stalk rot rating	1.4	1.0	1.0	1.3	1.2
Pith cond. rating	1.1	1.4	1.0	1.0	1.1
4th					
Pith core density	0.45	0.41	0.45	0.59	0.48
Stalk rot rating	4.6	4.0	1.9	2.4	3.2
Pith cond. rating	3.7	3.9	2.7	2.7	3.2
Oh41 1st					
Pith core density	0.81	0.66	0.46	0.48	0.60
Stalk rot rating	3.2	3.0	2.0	2.0	2.5
Pith cond. rating	3.6	2.6	2.2	3.0	2.9
4th					
Pith core density	0.35	0.29	0.32	0.30	0.32
Stalk rot rating	3.4	4.0	3.3	2.6	3.3
Pith cond. rating	4.0	4.0	4.0	3.9	4.0

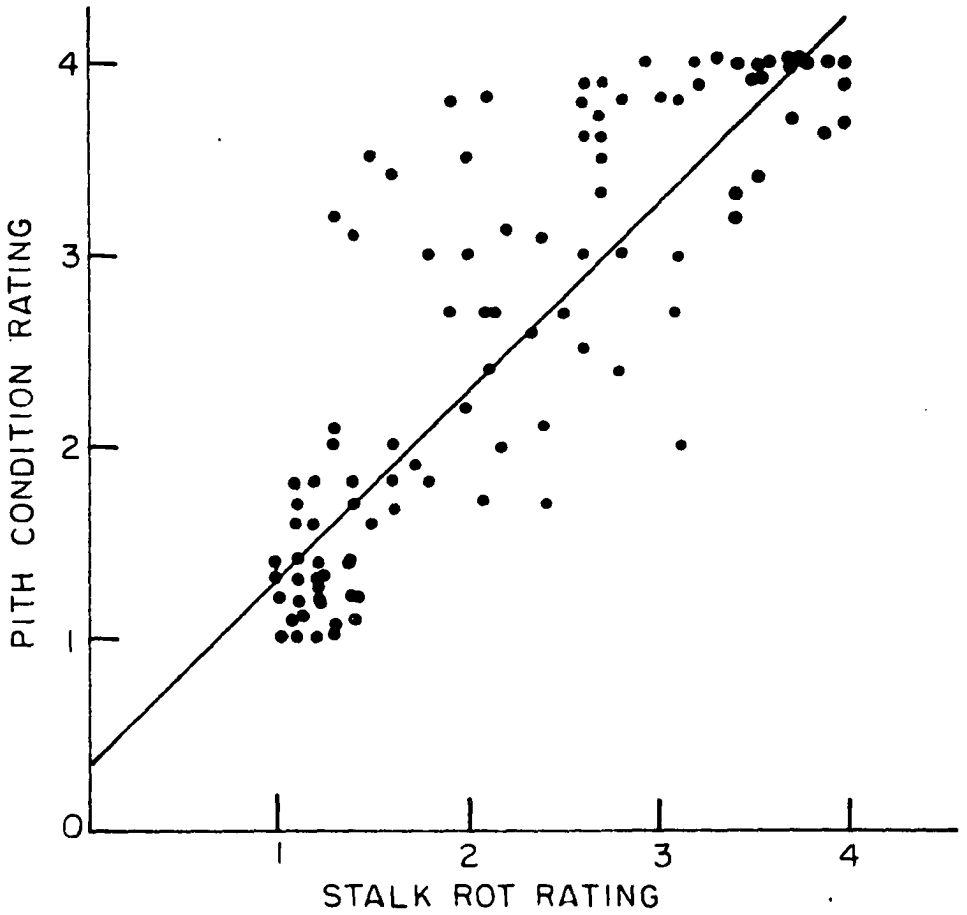
Table 9. (Continued)

Variety and treatment	Replicate 1	2	3	4	Field average
187-2 1st					
Pith core density	0.69	0.87	0.74	0.79	0.77
Stalk rot rating	2.0	1.3	1.0	1.3	1.4
Pith cond. rating	3.5	2.1	1.4	2.0	2.3
4th					
Pith core density	0.34	0.47	0.40	0.45	0.42
Stalk rot rating	3.4	2.9	2.8	2.7	3.0
Pith cond. rating	4.0	4.0	3.0	3.7	3.7
B14 x OS420 1st					
Pith core density	0.67	0.93	0.96	0.96	0.88
Stalk rot rating	1.7	1.2	1.2	1.1	1.3
Pith cond. rating	1.4	1.2	1.0	1.1	1.2
4th					
Pith core density	0.29	0.50	0.65	0.44	0.47
Stalk rot rating	4.9	4.3	2.1	3.5	3.7
Pith cond. rating	4.0	4.0	2.7	3.4	3.5
38-11 1st					
Pith core density	0.71	0.71	0.85	0.86	0.78
Stalk rot rating	1.8	1.4	1.4	1.2	1.8
Pith cond. rating	3.0	1.8	1.2	1.6	1.9
4th					
Pith core density	0.33	0.32	0.39	0.47	0.38
Stalk rot rating	4.2	3.7	2.1	----	3.3
Pith cond. rating	4.0	4.0	3.8	----	3.9
Wf9 1st					
Pith core density	0.93	0.84	0.91	0.87	0.88
Stalk rot rating	1.6	1.0	1.4	1.3	1.3
Pith cond. rating	1.8	1.0	1.4	1.0	1.3
4th					
Pith core density	0.42	0.34	0.47	0.64	0.47
Stalk rot rating	3.8	3.3	1.9	1.3	2.6
Pith cond. rating	4.0	4.0	3.8	3.2	3.8
B37 1st					
Pith core density	0.95	0.99	0.90	0.90	0.94
Stalk rot rating	1.1	1.1	1.1	1.4	1.2
Pith cond. rating	1.7	1.3	1.6	1.4	1.5

Table 9. (Continued)

Variety and treatment	Replicate 1	2	3	4	Field average
4th					
Pith core density	0.55	0.58	0.40	0.44	0.49
Stalk rot rating	3.5	3.4	3.9	3.0	3.4
Pith cond. rating	3.9	4.0	4.0	3.8	3.9
OS420 1st					
Pith core density	0.48	0.65	0.39	0.78	0.58
Stalk rot rating	4.2	3.9	3.1	2.8	3.5
Pith cond. rating	4.0	3.6	3.0	2.4	3.3
4th					
Pith core density	0.24	0.34	0.20	0.58	0.34
Stalk rot rating	4.5	4.6	4.0	----	4.4
Pith cond. rating	4.0	4.0	4.0	----	4.0
B14 x Oh41 1st					
Pith core density	0.65	0.66	0.75	0.91	0.74
Stalk rot rating	1.7	1.1	1.2	1.2	1.3
Pith cond. rating	1.9	1.2	1.4	1.0	1.4
4th					
Pith core density	0.24	0.37	0.27	0.36	0.31
Stalk rot rating	4.2	4.5	2.7	2.4	3.5
Pith cond. rating	4.0	4.0	3.9	3.1	3.8

Figure 28. Relationship between pith condition ratings and stalk rot ratings of the first and fourth internodes for the 20 varieties on September 6, 1956. Each point represents the replicate average for these measurements given in Table 9.


PITH CONDITION RATING
0
1
2
3
4
1
2
3
4
STALK ROT RATING

rot and pith condition measurements are crude, further study of pith conditions on a cellular level was required for a better understanding of the relationship.

Density of the internodal pith

Density of the internodal pith again was determined throughout the experimental period at approximately two week intervals beginning July 18 and ending September 7. The density of pith cores of first internodes was determined on all sample dates and of fourth internodes on August 4 and September 7. Replicate averages representing the pith core density of three subsamples and field averages are given in Table 17 in the Appendix, for first and fourth internode pith cores. Field averages alone are given in Table 10 in this section.

Sixteen of the 20 varieties studied had stalk rot ratings below 2.0 for field averages. These varieties were high in density, generally above 0.70 density units. Three varieties, B2, B14, and R101, were rated 1.0 for stalk rot in every replicate and had a field average for pith core density of about 1.00 on all sample dates. Variety W22R with a field average of 2.3 also was in this general grouping above 0.70 density units. It started at about 0.85 density units on July 18 and decreased to about 0.70 units in late August.

A reversal of the general trends in density and stalk rot ratings occurred in varieties Oh41, and OS420. Variety OS420

Table 10. Field average for density (grams of fresh weight per cc.) of first and fourth internode pith core tissue in 1956. (First internode = 1st, fourth = 4th)

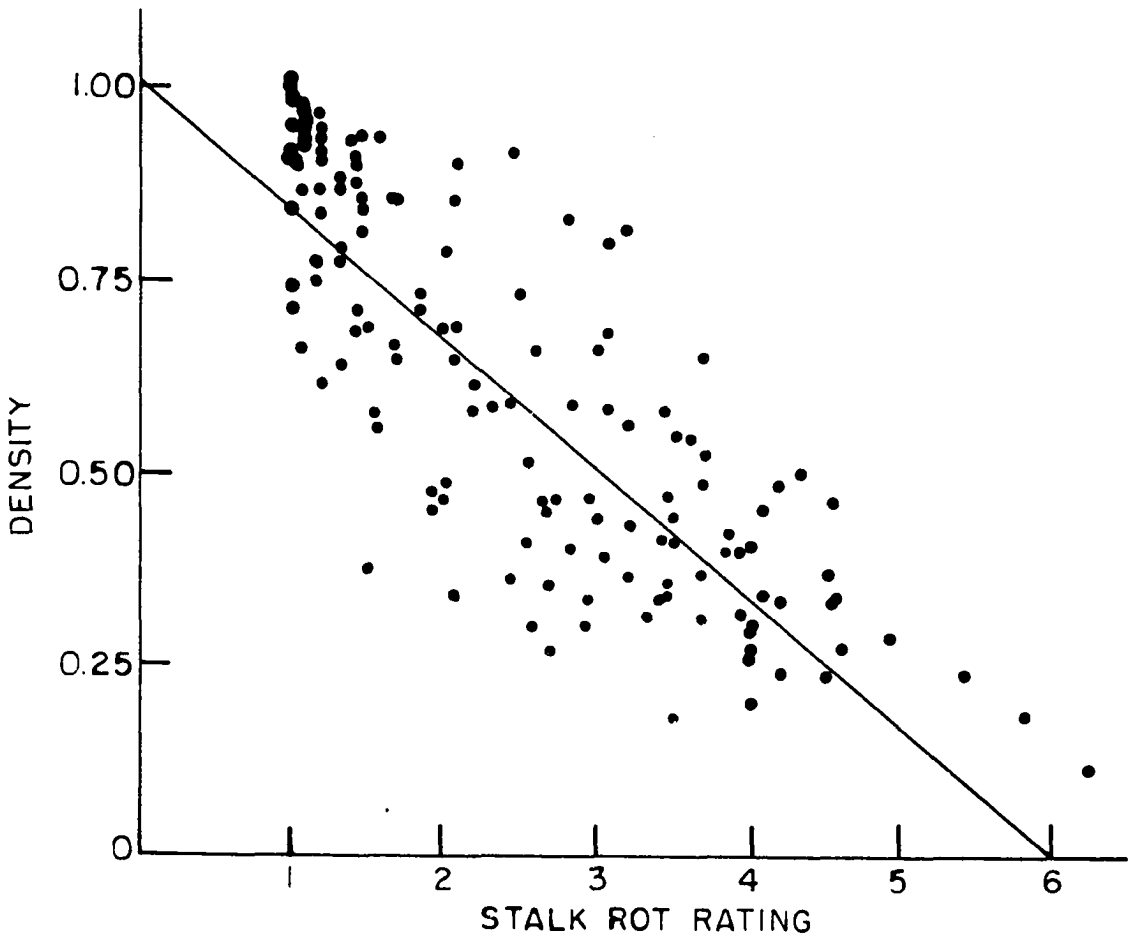
Variety	Sample date						
	July 18	Aug. 4		Aug. 15	Aug. 31	Sept. 7	
	1st	1st	4th	1st	1st	1st	4th
Ia153	0.62	0.54	---	0.48	0.30	0.18	---
Oh29	0.71	0.68	0.39	0.68	0.73	0.64	0.41
M14	0.89	0.91	0.53	0.96	0.92	0.91	0.48
R101	0.95	0.99	0.56	0.99	0.98	0.98	0.61
W22R	0.85	0.89	0.46	0.87	0.71	0.74	0.38
B2	1.00	1.01	0.99	0.98	1.02	1.01	0.99
B14	0.95	1.00	0.62	1.00	1.01	1.01	0.62
W17RB	0.95	0.93	0.62	0.94	0.73	0.86	0.48
Wf9 x 38-11	0.79	0.84	0.38	0.80	0.74	0.77	0.41
Wf9 x M14	0.81	0.94	0.42	0.81	0.78	0.80	0.39
C131 x B14	0.82	0.86	0.38	0.82	0.80	0.88	0.35
Wf9 x B14	0.91	0.97	0.50	0.95	0.88	0.92	0.48
Oh41	0.56	0.55	0.28	0.50	0.49	0.60	0.32
187-2	0.75	0.83	0.45	0.77	0.72	0.77	0.42
B14 x OS420	0.87	0.88	0.45	0.93	0.84	0.88	0.47
38-11	0.79	0.77	0.41	0.72	0.75	0.78	0.38
Wf9	0.93	0.98	0.43	0.95	0.94	0.88	0.47
B37	0.87	0.89	0.46	0.88	0.88	0.94	0.49
OS420	0.59	0.70	0.37	0.66	0.49	0.58	0.34
B14 x Oh41	0.86	0.84	0.32	0.79	0.79	0.74	0.31

averaged about 0.65 density units through July and early August, dropped to about 0.50 density units on August 31 but increased to about 0.55 density units by September 7. On that date, the field average for stalk rot rating for this variety was 3.5. Variety Oh41 began at 0.55 density units on July 28, dropped to about 0.50 density units by mid-August, maintained this level to August 31 but then increased to an average of about 0.60 density units on September 7. Yet this variety had a field average for stalk rot rating of 2.5 on this latter date. Why this difference in stalk rot rating and pith density existed with these varieties was not known. It can only be suggested that sampling of stunted plants of variety OS420 and probably Oh41 occurred on September 7.

In fourth internodes, only variety B2 had a high pith core density, about 0.98, at both dates. The majority of the varieties ranged from 0.30 to 0.50 in density and tended to be or were susceptible. No fourth internode measurements were obtained for variety Ial53 because of poor stand in all replicates.

The density data for pith cores from both positions of stalk tissue and their stalk rot ratings were highly correlated, $r = -0.87$. The data given in Table 9 for both positions were pooled for analysis and are presented graphically with the appropriate regression line in Figure 29. Density of the pith cores also was highly correlated with pith condition ratings, $r = -0.90$. The data for both stalk positions

Figure 29. Relationship between grams of fresh weight per cc. (density) for pith core tissue and stalk rot ratings of the first and fourth internodes for the 20 varieties on September 6, 1956. Each point represents the replicate average for these measurements given in Table 9.


1.00
0.75
0.50
0.25
0
DENSITY
1
2
3
4
5
6
STALK ROT RATING

given in Table 9 were pooled for the analysis and are presented graphically with the appropriate regression line in Figure 30.

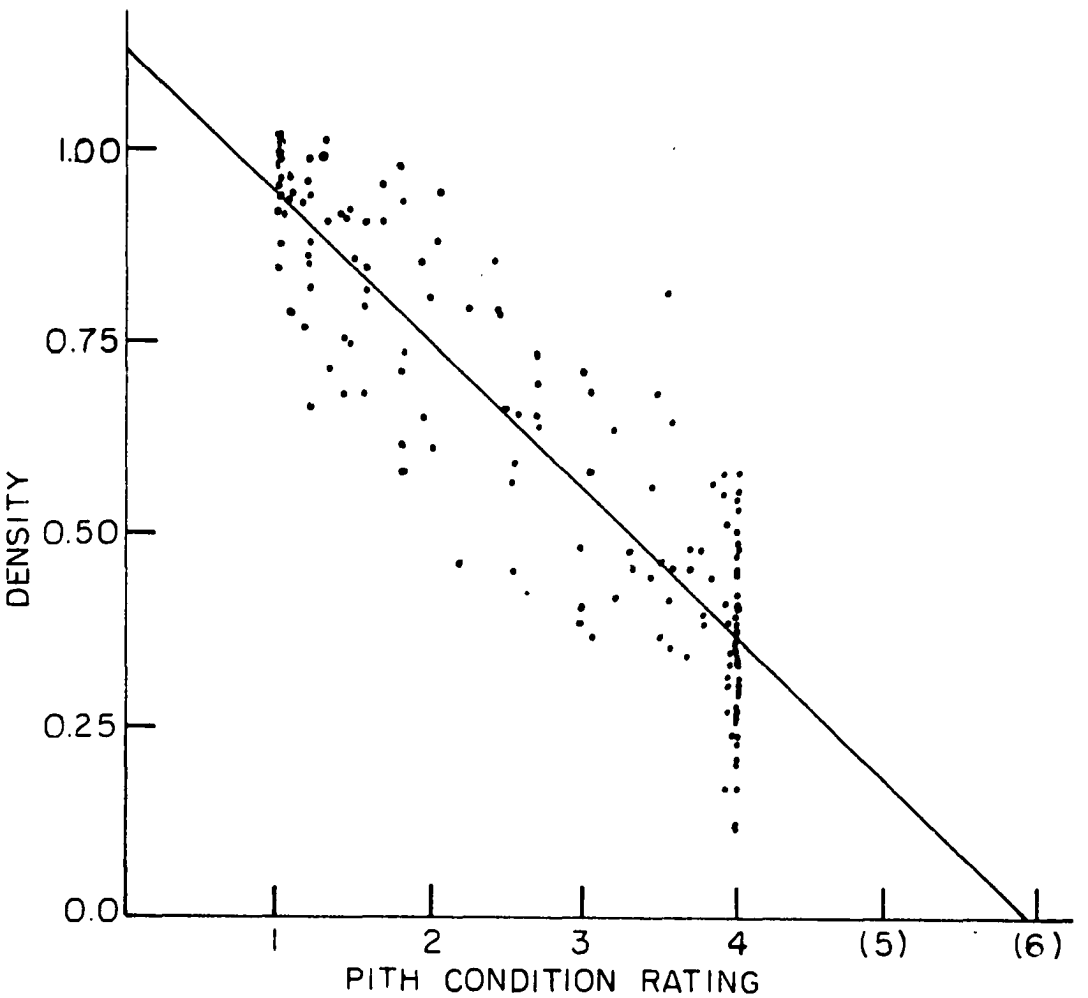
Since density of pith cores was highly correlated with stalk rot ratings and with pith condition ratings; and, as previously discussed, pith condition and stalk rot ratings also were highly correlated; these three factors were believed to be a common measure of some condition existing in the stalk of the plants which was closely related to the mechanism of resistance to spread of the organism in the tissue. These correlations were in good agreement with those reported in 1955. Therefore, it appeared likely that the mechanism of resistance was the same in all varieties tested, and was the same within the plants in lower or upper internodes. The mechanism was believed to be related in some way to water content of the pith tissue.

Physiological state of the internodal pith

In order to understand the significance of the relationship of pith ratings to stalk rot ratings first observed in 1955, a study of this condition on a cellular level was attempted in 1956. The purpose was to determine the difference between the well hydrated and the spongy dry pith tissue.

In the first week of July, cross sectional slices were made of internodal tissue of variety B2, and these were examined microscopically. A preliminary study using this tissue showed that neutral red, a vital stain, and plasmolytic

Figure 30. Relationship between grams of fresh weight per cc. (density) of pith core tissue and pith condition ratings of the first and fourth internodes for the 20 varieties on September 6, 1956. Each point represents the replicate average for these measurements given in Table 9.


1.00
0.75
0.50
0.25
0.0
DENSITY
1
2
3
4
(5)
(6)
PITH CONDITION RATING

solutions were suitable for the detection of living protoplasts in the stalk tissue of this variety. The thin slices, about 100, 200, and 400 microns, obtained by means of a sliding microtome showed an even distribution of plasmolyzed and red-stained protoplasts throughout the section after 10 to 20 minutes in the staining and plasmolyzing solution described by Tribe (52). Cells killed by autoclaving showed no plasmolyzed or stained protoplasts. Cell walls appeared stained to some extent under all conditions. Since this method appeared to be suitable for the study of cornstalk tissue, it was adopted as a means of determining the distribution of living cells in the well hydrated and spongy dry tissue.

On July 11, stalks of varieties B2, B14, Wf9, 38-11, and OS420 were collected at the rate of one stalk per replicate from a three replicate experiment adjacent to the 20 variety experiment. Cross sectional slices of 200 and 400 microns were cut from the center section of the first through fourth internodes using a sliding microtome. Half of the slices of each internode of each variety were placed in petri dishes containing water and the other half were placed in a neutral red plasmolyzing solution. The slices in water then were autoclaved for 15 minutes and placed in a neutral red plasmolyzing solution. After 20 minutes of staining, all of the slices were washed in plasmolyzing solution alone and observed under the microscope. No stained or plasmolyzed

protoplasts were observed in the autoclaved slices. Those slices not autoclaved showed a uniform distribution of well stained and plasmolyzed protoplasts in the hydrated tissue while no protoplasts were visible in the dry spongy type tissue. When cells in the latter tissue were pressed with a dissecting needle, the internal atmosphere of the cells escaped. The area of dead air-filled cells observed microscopically corresponded well with the macroscopically visible dry spong tissue. However, vascular bundles in the latter type tissue were surrounded on the average by a layer of three to five parenchyma cells which were well stained and plasmolyzed. On this date, the stalk tissue of variety B2 observed in the first through fourth internodes showed a uniform distribution of living cells as determined by this method and had no tissue which could be called spongy or dry by macroscopic observation. It was assumed, therefore, that the stalk tissue of the internodes was living throughout. Similar observations were made on the lower internodes of Wf9 and B14, but the upper internodes did contain dead air-filled cells visible macroscopically as the spongy dry type tissue. This latter type of tissue was found throughout the other varieties. Since the difference in tissues macroscopically described as hydrated or dry tissue was shown to depend on the presence of living cells or dead air-filled cells, the term living will be substituted for hydrated tissue and the term dead for dry spongy tissue.

On July 26, the first internodes of these varieties again were investigated as above using freshly collected stalk tissue. Similar results were obtained in all stalks examined. The resistant varieties were composed of living tissue and the susceptible varieties had dead tissue within the central region of the internodal pith.

On August 4, all 20 varieties were investigated for the reaction to the stain and plasmolyzing solution. Hand sections of the first and fourth internodes of the stalks were placed in the neutral red plasmolyzing solution and examined under a stereo-dissecting microscope. The hand sections were taken from the mid-point of the internodal tissue remaining after the pith core had been removed in the density study. If all of the spongy internodal pith had been removed in the pith core, the adjacent internode was used to obtain a hand section. In every plant sampled in the lower and upper internode, the well-hydrated tissue was always shown to consist of uniformly distributed stained and plasmolyzed protoplast characteristic of living cells, and the spongy tissue was always found to contain no stained or plasmolyzed protoplasts indicating that these cells were dead. The vascular tissue in the dead pith again was surrounded by living parenchyma cells. No samples were taken from upper or lower pith tissue of these internodes, and it must be assumed that the hydrated tissue in these areas and of the node were composed of living cells. It was concluded that the pith condition rating was a

measure of the extent of dead tissue in the internode.

After the study of the relationship between pith condition ratings, stalk rot ratings, and density had been completed, randomly selected inoculated stalks were studied using the neutral red stain and plasmolytic technique to determine the position of discoloration and mycelia in respect to living cells in the internodal pith. Cross sections of the inoculated stalks were made with a sliding microtome. Best sections for microscopic examination were obtained from plants not severely rotted, usually with a stalk rot rating below 2. Figures 31 through 34 show the typical examples of the relationship between the extent of discoloration after inoculation and the extent of dead tissue.

Sections like those in Figures 31 and 32 were first examined for the location of the discoloration and the position of the mycelia using unstained sections. Figure 37 shows a typical observation. Mycelial growth always was observed in the discolored area but no mycelia were observed beyond this region of heavy discoloration. The tissue adjacent to the heavy discoloration contained some pigments in the intercellular spaces. When the sections were stained, the same area again was observed. Figures 36 and 35 are representative of the sections that were stained and plasmolyzed. Figure 35 is a low power view of a typical section. Figure 36 is a high power view of the tissue next to the vascular bundle on the left in Figure 35. The tissue

Figure 31. (upper left) Cross sections of a normal and an inoculated first internode of variety WF9 x 38-11 on September 26, 1956 showing the extent of discoloration and white spongy dead pith tissue. The sections were cut at the inoculation position. These internodes would have a pith condition and stalk rot rating of about 1.

Figure 32. (upper right) Cross sections of a normal and an inoculated first internode of variety WF9 x 38-11 on September 26, 1956 showing the extent of discoloration and white spongy dead pith tissue. The sections were cut at the inoculation position. These internodes would have a pith condition and stalk rot rating of about 2.

Figure 33. (lower left) Cross sections of a normal and an inoculated first internode of variety B37 on September 26, 1956 showing the extent of discoloration and white spongy dead pith tissue. The sections were cut at the inoculation position. These internodes would have a pith condition and stalk rot rating of about 3.

Figure 34. (lower right) Cross sections of a normal and an inoculated first internode of variety Oh41 on September 26, 1956 showing the extent of discoloration and white spongy dead pith tissue. The sections were cut at the inoculation position. These internodes would have a pith condition and stalk rot rating of about 4.

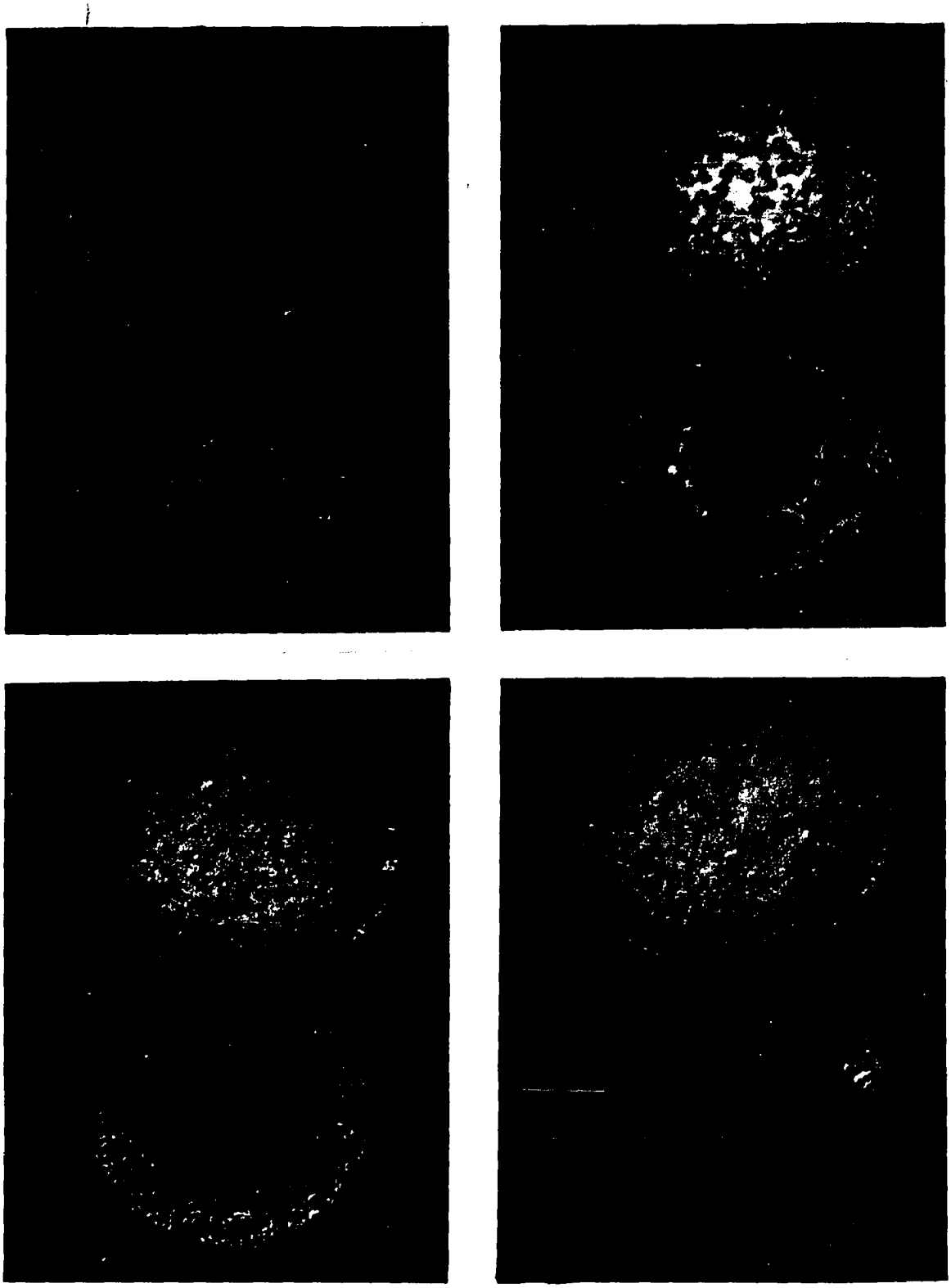
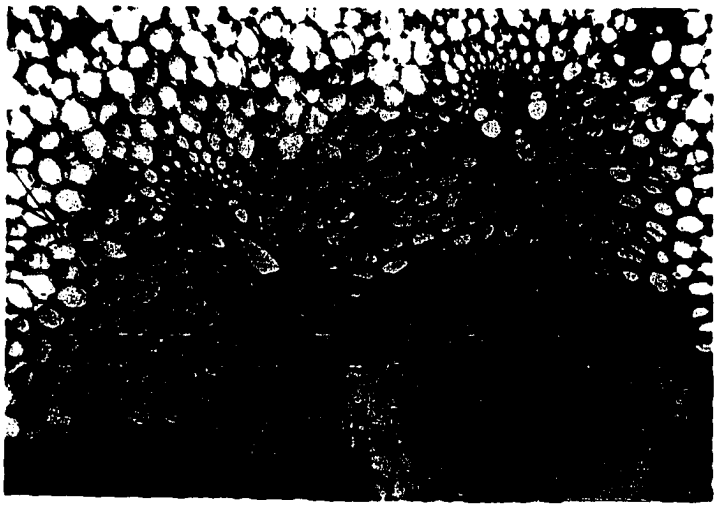


Figure 35. Photomicrograph of a cross section (about 75x) of inoculated first internode tissue of variety Oh41 on September 26, 1956 showing a uniform distribution of plasmolyzed protoplasts stained by neutral red in undiscolored tissue. Mycelia were localized in the discolored dead tissue.

Figure 36. Photomicrograph of a cross section (about 200x) of the tissue adjacent to and including part of the vascular bundle to the left in Figure 35.

Figure 37. Photomicrograph of a cross section (about 200x) of inoculated first internode stalk tissue of variety Wf9 x 38-11 on September 26, 1956 showing the localization of mycelia in the discolored dead tissue and small amounts of pigments accumulating in the intercellular spaces adjacent to the heavily discolored tissue.



adjacent to the heavily discolored area was composed of living cells, and the protoplasts were well stained and plasmolyzed. The amounts of intercellular pigments were sometimes masked by the red color of the cell walls. Mycelia were not observed to penetrate into or between these living cells. Most of the observations were made on varieties B2, Wf9, and 38-11. The photomicrographs were taken on September 26 but, as stated, were typical of observations made throughout the season.

On September 26, the last observations of the 1956 material were made primarily on varieties Wf9 x 38-11, B37, and Oh41. All observations were similar to those just reported. Since no isolations were made from the tissue for the purpose of identification of the organism, it can only be assumed that it was Diplodia zeae since this was the organism inoculated into the tissue, and fruiting bodies of this organism had been observed in the internodal tissue of susceptible varieties in late August. It is concluded that the pith density is a crude measure of the proportion of living cells of the pith tissue, that the pith condition rating estimates the distribution of the primarily dead areas of the tissue, and that the living cells in some unknown manner inhibit the spread of the fungus.

DISCUSSION AND CONCLUSIONS

Differences in the extent of hydration of pith tissue of resistant and susceptible varieties were noticed in 1954, but these differences were not evident in moisture content determinations based on fresh weight. However, in 1955, moisture content expressed on a unit volume basis clarified the situation. The internodal pith core tissue of resistant varieties was firm, well hydrated, and contained about 0.9 g. of water per cc. on July 26, 0.6 g. on September 14, and 0.4 g. on October 4. By the latter date, the pith had changed from the turgid condition and was spongy with a dry to crumbly texture. In susceptible varieties, this spongy condition of the pith was noticeable at the beginning of the experiment. On July 26, the susceptible varieties had less than 0.6 g. of water per cc. of pith core tissue and by September 14 had decreased to 0.4 g. per cc. or less. Plants which were lower than 0.4 g. per cc. were highly susceptible at that time and were dead by October.

On September 14, the grams of water per cc. of pith core tissue was highly correlated with stalk rot ratings. Resistance to stalk rot was associated with high water content and susceptibility with low water content. Although water content of the whole internodes was similarly correlated, the measurements on pith core tissue more clearly separated the stalk

rot rating groups. It was concluded that some condition of the pith tissue dependent on water content was closely related to the resistance mechanism.

Density of the pith core and whole internode tissue followed trends similar to those of water content throughout the 1955 season and also was highly correlated with stalk rot ratings on September 14. High density tissue was associated with resistance and low density tissue with susceptibility. Density and water content of pith core and whole internode tissue were highly correlated and were believed to be related to the pith condition appearance. Tissue of high density and, therefore, high water content, appeared well hydrated and was firm. Tissue of low density and, therefore, low water content, was white in appearance, compared to well hydrated tissue and tended to crumble when cut. These differences in appearance were used to rate the extent of white, dry tissue on the same area scale used for discoloration. Since these pith condition ratings compared well with stalk rot ratings on September 14, it was assumed that they also were correlated with water content and density of the tissue. However, no data for pith ratings were recorded and this assumption was not tested until 1956.

Comparisons between pith condition and stalk rot ratings were made on September 22 and October 11 in 1955. On September 22, comparative ratings were made on both first and fourth internodes, the latter being more susceptible than the

former. A high correlation existed over a wide range of stalk rot and pith condition ratings. Ratings on October 11 for stalk rot in the first internode were higher than those for the same internodes on September 22. The pith condition and stalk rot ratings again were highly correlated. It was concluded that the extent of discoloration following inoculation was in some way dependent on the pith condition. Since water content and density decreased with time, and stalk rot and pith condition ratings increased with time, it was concluded that the decrease in water content was the cause of the density decrease and was a useful measure of the pith condition change and also of the increase in susceptibility.

In 1956, pith core density and pith condition ratings for both first and fourth internodes were highly correlated with stalk rot ratings in these positions. The experiment verified the previous findings on the six varieties studied in 1955 and extended the findings to eight other inbreds and six single cross varieties. This study also showed a high correlation between pith condition ratings and pith core density verifying the previous assumption and indicating that both were a measure of some common property of pith tissue involving water content.

In 1955, the differences among resistant and susceptible varieties in water content suggested that the living state of the tissues might be the primary factor being measured, and that both density and pith condition ratings were related to

the number and distribution of living cells. This assumption was tested in 1956.

The pith condition studies in 1956 using neutral red and plasmolytic solutions showed a uniform distribution of stained and plasmolyzed protoplasts in well hydrated tissue but no similar reaction in the spongy white tissue. It was apparent that the latter type of tissue, in which the cells were largely air-filled, was dead. The pith condition ratings thus were considered to be a measure of the distribution of dead cells, and the density and water content indices were gross measures of the ratio of living to dead cells. The only living cells observed in the spongy dry area used in pith condition ratings surrounded vascular bundles. Since these pith condition ratings were highly correlated with the area of discoloration following inoculation, and since vascular bundles and the inner margin of the hydrated tissue were heavily discolored, it was concluded that the discoloration reaction was closely associated with living cells.

Further study of inoculated tissue using the stain and plasmolytic solutions showed that the tissue outside that discolored was composed of living cells and that no observable penetration of hyphae had occurred beyond the discolored tissue. It was concluded, therefore, that the spread of the organism was in some way inhibited by living cells adjacent to the highly discolored dead tissue. Whether the discoloration reaction killed these marginal cells before fungal

penetration or the discoloration occurred after penetration is not clear. It is suggested that the former is the case, since the work of Johann and Dickson (24) and Roberts (43) reporting discoloration in advance of the mycelia supports this suggestion.

Since resistance is associated with the ability of the living pith tissue to restrict the advance of the pathogen, it is understandable that total dissolved solids, total dry matter, and insoluble dry matter were not found to be closely related to stalk rot ratings. Both living and dead tissue contain soluble and insoluble dry matter and the organism has been demonstrated to utilize such insoluble dry matter as cellulose and, to a lesser extent, lignin as well as soluble carbohyrates (10, 11, 24, 38, 43). Taylor (51) also showed that the organism grew best on expressed sap containing high percentages of soluble material. These tests were carried out in culture and for that reason could not be related to the site of action of the organism in the tissue. Durrell (10) also pointed out the fact that the organism was saprophytic but based his conclusions on soil culture tests. The present observations on inoculated host tissue suggest that the organism, D. zeae, is indeed a weak parasite; but further study to determine its ability to attack living cells is necessary. An answer to this question would provide a better understanding of the relationship of D. zeae to the stalk rot syndrome which is believed to involve a number of organisms.

In considering how the physiological processes of the living cells might be involved in resistance to spread of the organism, it seems most likely that an inhibitor is formed. Furthermore, it seems probable that the formation of the inhibitor is related to the discoloration reaction. Davis and Dimond (6) and Dimond (9) suggested that the discoloration symptoms in Fusarium infected tomatoes involved phenols. They suggested that these phenols were derived from enzymatic hydrolysis of beta glycosides, which normally release phenolic compounds for lignin synthesis, or from hydrolysis of tannins. The infected tomato plants contained less lignin and fewer lignified cells than healthy plants, and the authors believed that this decrease in lignin could arise by the shunting of phenols to melanin formation at the expense of lignin synthesis. Siegel (49) has pointed out that phenols and phenol-oxidizing enzymes are involved in lignin synthesis.

Durrell (11) found that stalk rot resistant varieties of corn contained more lignified tissue than did susceptible varieties, particularly in the lower nodes of the stalk. Johann and Dickson (24) reported that discolorations resulting from early inoculations were darker in color than those resulting from later inoculations and that resistant varieties were more highly discolored than susceptible varieties. Roberts found that vascular bundles discolored in advance of the organism and that lignified tissue did not prevent penetration by D. zeae but did slow down the process. In the

present study, similar results concerning intensity and localization of discoloration were observed. Heavy discoloration was noted along vascular bundles and the inner margin of living tissue. The relationship between discoloration of the pith tissue and phenolic compounds can only be suggested, for the nature of the discoloration reaction in the corn stalk has not been studied. Since all varieties examined in 1954 and 1955 increased in insoluble dry matter during the experimental period, it is likely that lignin synthesis did continue. For the purpose of further discussion, it is assumed that the discoloration reaction observed following inoculation is phenolic.

Many cases of resistance to diseases of plants have been associated with phenolic substances. In onion smudge (57), the toxic phenols in the outer dead scales of the colored onions are free to diffuse and act as fungicides. In the epidermal cells of living fleshy and colored scales, the phenols do not exist in the free form and are functionless as a resistant principle. When the living cells are attacked, the phenols are destroyed or polymerized forming non-toxic compounds. In this case, the dead outer scales are involved in resistance while the living inner tissue, although containing phenols, are not.

In the potato tuber (57), living periderm cells contain chlorogenic acid. These cells of potatoes resistant to the common scab organism contain more of this phenolic acid than

do those of the susceptible potatoes. This phenolic acid and its quinones accumulate in the periderm when injured mechanically or parasitically. The concentration of the phenolic acid and other ortho-dihydroxyphenols recently were shown (26) to be higher in the resistant varieties than in the susceptible ones during early stages of tuber growth, the period in which the organism causes the most infection. Cooper, et al. (5) reported that in the susceptible potato, the common scab organism became established as a saprophyte in the dead cells of the periderm tissue and stimulated the development of meristematic tissue which develops and forms the scab lesion. In resistant varieties, the periderm is not covered by the layers of dead cells and for that reason fungal establishment without wounding is not possible.

Uritani and Muramatsu (54, 55) and Uritani and Akazawa (53) found that discoloration of sweet potato tissue infected by Cerotostomella fimbriata resulted from the enzymatic oxidation of polyphenols, including chlorogenic and caffeic acids. The accumulation of these phenolic compounds in the wounded tissue and their irreversible oxidation was believed to aid in the destruction of cell function and to inactivate respiratory enzymes of the mycelia.

In stalk rot of corn following artificial inoculation, the situation resembles the saphrophytic establishment of the common scab organism in the potato in which accumulation of phenolic compounds in wounded tissue occurs. As in the sweet

potato, the accumulated phenols would destroy normal cell functions and inhibit the fungus. It is believed that the factors modifying resistance to stalk rot such as fertility, leaf clipping, prevention of pollination or ear removal, root cutting, or environment, may be involved in the processes governing the rate of dying of pith tissue. The carbohydrate content may be sufficiently high in all varieties during the period of ear formation and filling to provide a steady synthesis of potential substrate for discoloration reactions in living cells. Inoculation in the late periods when stalk pith tissue is composed of dead cells throughout, except along bundles and rind, would not cause discoloration except in these living areas. This would explain the inability to obtain discoloration in stalk tissue on late dates of inoculation. It is suggested, therefore, that the living tissue of the corn stalk continuously forms phenolic substances which, on wounding, are released as free phenols and accumulate to a level toxic to certain fungi. The oxidation and condensation of the toxic free phenols to the pigments would account for discoloration of the tissue. It would appear that this hypothesis involving phenols and phenolic reactions would be the most promising guide for further work on the mechanism of resistance to stalk rot of corn.

SUMMARY

1. No apparent correlation existed between stalk rot ratings and per cent total dissolved solids, mg. of total dissolved solids per cc. of tissue, per cent moisture on a fresh weight basis, mg. of total dry matter per cc. of tissue, or mg. of insoluble dry matter per cc. of tissue.
2. Since total sugars and sucrose were highly correlated with total dissolved solids when compared on a volume basis, it is assumed that no direct correlation existed between soluble carbohydrate content and stalk rot ratings.
3. Highly significant correlations existed between stalk rot ratings and pith condition ratings, whole internode density, internodal pith core density, grams of water per cc. of whole internode tissue and grams of water per cc. of internodal pith core tissue.
4. A highly significant correlation existed between stalk rot rating and per cent of natural crown rot. This relates the findings of the study on artificial inoculation responses to natural stalk rotting.
5. Spread of the organism in inoculated plants appeared to be inhibited by living cells adjacent to the highly discolored dead tissue.
6. It is suggested that the living tissue of the corn stalk continuously forms substances which, on wounding, are

released and accumulate to a level toxic to certain fungi. These substances are believed to be phenolic in nature. The oxidation and condensation of the toxic free phenols to pigments would account for discoloration of the tissue.

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APPENDIX

Table 11. Date of silking in each replicate in 1954. Date of silking is that date on which 50 per cent of the ear bearing plants showed 1 inch of silks

Variety	Replicate		
	1	2	3
Wf9	July 26	July 27	July 26
38-11	August 7	August 7	August 6
Oh41	August 1	August 3	August 1
OS420	July 29	August 1	July 29
B2	August 2	August 3	August 2
B14	July 31	July 29	July 28

Table 12. Replicate and field averages of moisture content as per cent of fresh weight (moisture %), per cent toal dissolved solids in expressed stalk sap (TDS %), mg. total dissolved solids per cc. of tissue (mg. TDS per cc.), mg. total dry matter per cc. of tissue (mg. TDM per cc.), and grams of fresh weight per cc. of tissue (density) of normal and defruited plants in 1954. All measurements except per cent total dissolved solids refer to whole first internode above the uppermost brace roots. The exception was measured in second internode tissue and was used to calculate the mg. total dissolved solids per cc. of first internode tissue. The replicate average of all indices are based on three stalk samples for normal plants and two stalk samples for defruited plants

Variety treatment and replicate	Moisture %	TDS %	Mg. TDS per cc.	Mg. TDM per cc.	Density
		July 28, 1954			
Wf9					
Normal 1	81.3	10.1	87	186	1.00
2	80.1	10.8	80	186	0.93
3	82.3	11.2	82	162	0.90
Average	81.2	10.7	83	178	0.94
Defruited 1	79.9	9.9	77	195	0.98
2	77.3	12.9	99	227	1.02
3	81.2	11.3	77	160	0.85
Average	79.5	11.4	84	194	0.95
OS420					
Normal 1	84.5	8.2	63	141	0.91
2	84.9	8.0	54	118	0.78
3	81.9	8.9	64	152	0.88
Average	83.8	8.4	60	137	0.86
Defruited	No data obtained until August 11				
B14					
Normal 1	83.1	7.9	65	170	1.00
2	82.3	7.8	65	180	1.00

Table 12. (Continued)

Variety treatment and replicate		Moisture %	TDS %	Mg. TDS per cc.	Mg. TDM per cc.	Density
	3	82.7	7.2	58	169	0.98
Average		82.7	7.6	63	173	0.99
Defruited		No data obtained until August 11				
			August 4, 1954			
Wf9						
Normal	1	76.6	14.0	103	226	0.97
	2	75.6	12.6	87	221	0.90
	3	77.0	13.7	99	218	0.95
Average		76.4	13.4	96	222	0.94
Defruited	1	73.0	17.3	128	271	1.02
	2	73.1	16.4	115	258	0.96
	3	75.3	15.8	116	248	0.98
Average		73.8	16.5	120	259	0.99
38-11						
Normal	1	87.8	6.3	50	111	0.92
	2	84.0	6.5	53	121	0.94
	3	87.6	7.4	57	110	0.89
Average		86.5	6.7	53	114	0.91
Defruited		No data obtained until August 11				
Oh41						
Normal	1	86.9	9.2	72	122	0.92
	2	86.2	8.9	73	133	0.95
	3	85.9	9.2	73	128	0.88
Average		86.3	9.1	73	127	0.92
Defruited		No data obtained until August 11				
OS420						
Normal	1	84.7	9.8	76	146	0.94
	2	82.9	11.0	81	152	0.88
	3	83.4	10.6	81	155	0.90
Average		83.7	10.5	79	151	0.91
Defruited		No data obtained until August 11				

Table 12. (Continued)

Variety treatment and replicate		Moisture %	TDS %	Mg. TDS per cc.	Mg. TDM per cc.	Density
B2						
Normal	1	85.5	8.7	70	137	0.94
	2	84.0	9.0	81	172	1.07
	3	86.6	9.0	73	149	0.95
Average		85.4	8.9	75	153	0.99
Defruited		No data obtained until August 11				
B14						
Normal	1	81.1	8.1	67	185	1.01
	2	79.8	8.4	64	194	0.96
	3	77.5	8.8	67	219	0.95
Average		79.5	8.4	66	199	0.97
Defruited		No data obtained until August 11				
		August 11, 1954				
Wf9						
Normal	1	74.4	14.8	97	256	0,90
	2	76.6	14.9	112	234	0.99
	3	78.0	15.6	105	214	0.90
Average		76.3	15.1	105	235	0.93
Defruited	1	74.8	18.7	130	308	0.95
	2	72.9	16.5	123	279	1.03
	3	70.4	17.6	133	380	1.04
Average		72.7	17.6	129	322	1.01
38-11						
Normal	1	86.4	7.1	47	103	0.79
	2	87.4	7.8	52	106	0.76
	3	84.6	8.8	57	118	0.74
Average		86.1	7.9	52	109	0.76
Defruited	1	83.6	9.6	61	131	0.79
	2	85.3	8.9	66	130	0.87
	3	83.9	10.9	70	126	0.77
Average		84.3	9.8	66	129	0.81

Table 12. (Continued)

Variety treatment and replicate		Moisture %	TDS %	Mg. TDS per cc.	Mg. TDM per cc.	Density
Oh41						
Normal	1	86.0	9.8	78	130	0.93
	2	85.9	9.5	80	139	0.96
	3	86.6	9.7	78	124	0.90
Average		86.2	9.7	79	131	0.93
Defruited	1	84.5	11.4	91	146	0.95
	2	80.8	12.9	99	181	0.94
	3	83.8	11.2	81	140	0.86
Average		83.0	11.8	90	156	0.92
OS420						
Normal	1	81.6	12.4	94	170	0.94
	2	81.2	11.8	86	168	0.90
	3	80.0	12.3	82	166	0.84
Average		80.9	12.2	87	168	0.88
Defruited	1	78.3	13.5	86	176	0.81
	2	77.0	12.9	89	207	0.90
	3	75.9	15.2	89	187	0.78
Average		77.1	13.9	88	190	0.83
B2						
Normal	1	83.3	10.5	82	158	0.96
	2	83.4	10.0	72	162	0.87
	3	81.3	11.2	86	174	0.95
Average		82.7	10.6	80	165	0.93
Defruited	1	82.3	12.7	96	161	0.93
	2	78.6	11.9	89	192	0.94
	3	81.7	12.5	107	191	1.05
Average		80.9	12.4	97	181	0.97
B14						
Normal	1	76.4	10.3	70	215	0.91
	2	78.9	9.3	61	170	0.82
	3	80.3	9.8	76	206	0.97
Average		78.5	9.8	69	197	90
Defruited	1	75.2	11.1	80	197	0.96
	2	75.8	10.8	86	271	1.06

Table 12. (Continued)

Variety treatment and replicate		Moisture %	TDS %	Mg. TDS per cc.	Mg. TDM per cc.	Density
	3	74.6	10.9	76	241	0.89
Average		75.2	10.9	81	236	0.97
			August 18, 1954			
Wf9						
Normal	1	77.7	12.4	99	231	1.04
	2	75.8	13.4	93	225	0.91
	3	75.4	13.8	98	232	0.94
Average		76.3	13.2	97	229	0.96
Defruited	1	----	----	---	---	----
	2	68.6	17.2	121	285	1.03
	3	71.8	17.4	123	278	0.99
Average		70.2	17.3	122	284	1.01
38-11						
Normal	1	85.7	8.8	54	106	0.72
	2	84.9	9.2	62	121	0.81
	3	84.4	8.8	67	128	0.81
Average		85.0	8.9	61	118	0.75
Defruited	1	81.5	11.5	81	156	0.85
	2	80.0	11.5	72	158	0.76
	3	82.0	12.6	72	125	0.70
Average		81.2	11.9	75	146	0.77
Oh41						
Normal	1	87.1	9.0	72	119	0.92
	2	85.3	9.9	77	133	0.90
	3	85.8	10.0	80	131	0.93
Average		86.1	9.6	76	128	0.92
Defruited	1	79.1	16.4	134	217	1.04
	2	79.5	15.3	110	185	0.90
	3	81.1	14.1	118	195	1.03
Average		79.9	15.3	121	199	1.00
OS420						
Normal	1	81.7	11.8	83	160	0.88
	2	80.5	11.3	88	159	0.97

Table 12. (Continued)

Variety treatment and replicate		Moisture %	TDS %	Mg. TDS per cc.	Mg. TDM per cc.	Density
	3	79.3	12.9	83	167	0.81
Average		80.5	12.0	85	172	0.86
Defruited	1	76.1	11.5	84	229	0.96
	2	75.3	13.1	89	223	0.90
	3	77.7	11.6	80	195	0.88
Average		76.4	12.1	84	216	0.91
B2						
Normal	1	85.9	12.7	99	172	0.93
	2	80.6	13.2	101	184	0.95
	3	80.7	13.1	106	194	1.00
Average		81.7	13.0	102	183	0.96
Defruited	1	79.7	15.9	119	200	0.94
	2	75.6	17.8	135	244	1.00
	3	76.5	17.1	128	230	0.98
Average		77.3	16.9	127	225	0.97
B14						
Normal	1	77.9	10.2	73	208	0.93
	2	76.4	10.6	79	205	0.97
	3	79.7	10.2	78	193	0.95
Average		78.0	10.3	77	202	0.95
Defruited	1	76.7	14.0	105	230	0.99
	2	76.2	11.3	84	234	0.98
	3	73.3	13.6	92	251	0.92
Average		75.4	13.0	94	238	0.96
			August 25, 1954			
Wf9						
Normal	1	78.8	11.3	80	190	0.90
	2	78.6	10.7	79	202	0.93
	3	77.1	13.4	99	220	0.96
Average		77.2	11.8	86	204	0.93
Defruited	1	67.7	16.2	110	276	1.01
	2	71.9	14.5	105	285	1.01
	3	70.5	16.6	111	280	0.95
Average		70.0	15.8	109	280	0.99

Table 12. (Continued)

Variety treatment and replicate		Moisture %	TDS %	Mg. TDS per cc.	Mg. TDM per cc.	Density
38-11						
Normal	1	84.7	10.2	69	121	0.79
	2	83.6	9.8	66	133	0.81
	3	81.8	10.6	69	147	0.80
Average		83.4	10.2	68	134	0.80
Defruited	1	80.5	11.4	68	144	0.74
	2	79.3	11.1	77	177	0.86
	3	78.6	12.6	88	197	0.80
Average		79.5	11.7	78	173	0.80
Oh41						
Normal	1	86.8	8.6	70	124	0.94
	2	85.1	8.7	65	132	0.89
	3	86.3	9.2	70	121	0.88
Average		86.1	8.8	68	126	0.91
Defruited	1	80.0	15.0	114	187	0.95
	2	79.3	13.8	109	207	1.00
	3	80.9	12.1	90	180	0.95
Average		80.1	13.6	104	191	0.97
OS420						
Normal	1	81.2	12.2	97	185	0.98
	2	80.9	10.2	72	164	0.87
	3	82.8	10.3	67	134	0.79
Average		81.6	10.9	79	161	0.88
Defruited	1	69.9	12.3	84	280	0.93
	2	69.3	13.1	74	258	0.82
	3	71.3	14.9	91	247	0.86
Average		70.2	13.4	83	262	0.87
B2						
Normal	1	79.2	15.6	112	191	0.91
	2	77.3	16.9	131	227	0.94
	3	78.3	15.5	119	208	0.98
Average		78.3	16.0	121	209	0.94
Defruited	1	75.4	19.4	148	242	1.00
	2	73.4	19.3	136	246	0.91
	3	74.8	20.3	156	258	1.02
Average		74.5	19.7	147	249	0.98

Table 12. (Continued)

Variety treatment and replicate		Moisture %	TDS %	Mg. TDS per cc.	Mg. TDM per cc.	Density
B14						
Normal	1	75.3	11.8	80	225	0.89
	2	76.8	11.2	89	215	0.85
	3	77.9	12.3	93	216	0.97
Average		76.7	11.8	87	219	0.90
Defruited	1	72.5	16.0	108	256	0.93
	2	70.5	15.8	108	286	0.97
	3	70.2	16.5	111	286	0.96
Average		71.1	16.1	109	276	0.95
			September 1, 1954			
Wf9						
Normal	1	74.8	12.3	88	246	0.95
	2	78.6	10.2	71	191	0.89
	3	77.8	10.1	70	206	0.92
Average		77.1	10.9	76	214	0.92
Defruited	1	66.9	14.8	94	307	0.92
	2	70.9	13.6	82	249	0.94
	3	71.8	17.2	114	259	0.92
Average		69.9	15.2	97	272	0.93
38-11						
Normal	1	82.8	10.9	81	156	0.86
	2	82.9	11.1	72	134	0.78
	3	82.9	10.3	66	132	0.77
Average		82.9	10.8	73	141	0.80
Defruited	1	78.1	12.0	54	121	0.59
	2	78.2	12.5	75	166	0.76
	3	77.8	11.4	83	208	0.93
Average		78.0	12.0	71	165	0.76
Oh41						
Normal	1	87.6	7.5	61	116	0.94
	2	87.5	7.9	55	105	0.84
	3	86.5	8.6	67	122	0.90
Average		87.2	8.0	61	114	0.89
Defruited	1	78.1	12.7	93	204	0.93
	2	78.8	15.6	115	199	0.94

Table 12. (Continued)

Variety treatment and replicate		Moisture %	TDS %	Mg. TDS per cc.	Mg. TDM per cc.	Density
	3	80.3	14.3	107	185	0.94
Average		79.1	14.2	105	196	0.94
OS420						
Normal	1	81.6	9.5	68	161	0.88
	2	78.9	12.1	83	183	0.86
	3	79.9	10.1	63	131	0.68
Average		80.1	10.6	71	158	0.81
Defruited	1	74.4	13.9	75	187	0.73
	2	----	----	--	---	----
	3	70.2	13.5	80	250	0.85
Average		72.3	13.7	78	219	0.79
B2						
Normal	1	79.5	15.7	118	197	0.96
	2	77.7	16.9	119	202	0.91
	3	77.0	18.0	135	229	1.00
Average		78.1	16.9	124	209	0.96
Defruited	1	77.0	19.8	158	238	1.04
	2	70.1	21.0	134	273	0.91
	3	72.2	21.3	153	277	1.00
Average		73.1	20.7	148	263	0.98
B14						
Normal	1	74.8	12.2	88	246	0.98
	2	75.4	12.0	91	251	1.01
	3	81.3	8.7	64	174	0.89
Average		77.2	11.0	81	224	0.96
Defruited	1	71.4	17.2	126	292	1.03
	2	70.5	16.7	115	290	0.99
	3	70.0	16.7	128	329	1.09
Average		70.6	16.9	123	304	1.04
			September 9, 1954			
Wf9						
Normal	1	77.3	7.6	55	216	0.90
	2	78.0	6.8	68	213	0.85
	3	77.3	8.4	77	218	0.96
Average		77.5	7.6	67	216	0.90

Table 12. (Continued)

Variety treatment and replicate		Moisture %	TDS %	Mg. TDS per cc.	Mg. TDM per cc.	Density
Defruited	1	----	----	---	---	----
	2	73.1	12.7	91	295	1.00
	3	69.5	14.6	102	308	1.01
Average		71.3	13.5	97	302	1.01
38-11						
Normal	1	81.3	10.5	80	155	0.82
	2	80.6	11.9	72	147	0.75
	3	82.0	10.5	62	130	0.72
Average		81.3	11.0	71	144	0.76
Defruited	1	73.0	13.3	102	284	1.05
	2	73.2	14.6	79	191	0.73
	3	72.4	15.5	104	238	0.91
Average		72.9	14.5	95	238	0.90
Oh41						
Normal	1	86.9	6.1	53	136	0.74
	2	84.1	9.5	74	147	0.92
	3	86.2	8.4	62	119	0.86
Average		85.7	8.0	63	134	0.84
Defruited	1	79.8	15.0	119	201	1.00
	2	78.3	13.2	76	219	1.01
	3	79.4	7.2	51	185	0.90
Average		79.2	11.6	82	202	0.97
OS420						
Normal	1	80.6	8.6	64	181	0.93
	2	77.6	7.5	46	179	0.79
	3	78.1	9.7	65	190	0.86
Average		78.8	8.6	58	183	0.86
Defruited	1	75.0	11.7	69	117	0.95
	2	71.8	16.1	87	211	0.75
	3	----	----	--	---	----
Average		73.4	13.9	78	164	0.85
B2						
Normal	1	78.8	16.0	124	210	1.00
	2	78.3	15.2	123	226	1.04
	3	77.2	16.8	119	207	0.91
Average		78.1	16.0	122	214	0.98

Table 12. (Continued)

Variety treatment and replicate		Moisture %	TDS %	Mg. TDS per cc.	Mg. TDM per cc.	Density
Defruited	1	76.9	18.1	153	257	1.09
	2	74.8	19.7	155	265	1.05
	3	75.0	20.0	139	231	0.93
Average		75.6	19.3	149	251	1.02
B14						
Normal	1	75.6	11.2	83	257	0.97
	2	74.0	14.4	101	247	0.95
	3	73.2	13.9	97	247	0.94
Average		74.3	13.2	94	250	0.95
Defruited	1	71.7	15.2	108	282	1.00
	2	71.8	15.4	118	303	1.08
	3	73.1	17.0	117	254	0.95
Average		72.2	15.9	114	280	1.01
			September 16, 1954			
Wf9						
Normal	1	76.7	9.7	67	208	0.90
	2	77.4	8.6	59	201	0.88
	3	74.9	10.9	74	242	0.95
Average		76.3	9.7	67	217	0.91
Defruited	1	73.8	9.6	60	223	0.85
	2	74.3	11.0	85	250	0.97
	3	72.1	10.4	83	299	1.07
Average		73.4	10.3	76	257	0.96
38-11						
Normal	1	80.4	11.6	72	152	0.72
	2	81.4	9.9	72	166	0.90
	3	81.1	11.3	76	157	0.83
Average		81.0	10.9	73	158	0.85
Defruited	1	79.1	13.2	83	176	0.84
	2	77.0	12.8	82	191	0.83
	3	73.4	14.9	87	213	0.83
Average		76.5	13.6	84	193	0.82
Oh41						
Normal	1	86.8	4.8	27	84	0.66
	2	86.9	5.8	33	85	0.66
	3	87.3	7.3	55	109	0.86

Table 12. (Continued)

Variety treatment and replicate		Moisture %	TDS %	Mg. TDS per cc.	Mg. TDM per cc.	Density
Average		87.0	6.0	38	93	0.72
Defruited	1	79.5	12.9	101	201	0.98
	2	78.3	12.8	86	185	0.85
	3	81.1	14.6	98	157	0.83
Average		79.6	13.4	95	181	0.89
OS420						
Normal	1	82.2	6.4	38	127	0.71
	2	81.0	7.2	48	160	0.84
	3	78.8	8.8	49	145	0.67
Average		80.7	7.5	45	144	0.74
Defruited	1	72.4	16.5	90	209	0.76
	2	----	----	--	---	----
	3	71.4	14.8	76	205	0.71
Average		71.9	15.7	83	207	0.73
B2						
Normal	1	78.8	14.7	111	203	0.94
	2	79.4	13.5	103	199	0.96
	3	76.7	17.0	122	216	0.94
Average		78.3	15.1	112	206	0.95
Defruited	1	75.6	17.9	117	210	0.86
	2	----	----	---	---	----
	3	75.4	19.0	142	243	0.99
Average		75.5	18.5	130	227	0.93
B14						
Normal	1	77.6	9.5	65	193	0.87
	2	74.7	13.6	93	231	0.92
	3	76.5	13.4	96	220	0.96
Average		76.3	12.2	85	215	0.92
Defruited	1	73.0	15.9	109	250	0.94
	2	73.6	13.9	98	252	0.96
	3	68.1	15.3	106	325	1.03
Average		71.6	15.0	104	276	0.98

Table 12. (Continued)

Variety treatment and replicate		Moisture %	TDS %	Mg. TDS per cc.	Mg. TDM per cc.	Density
			September 21, 1954			
38-11						
Normal	1	77.9	11.7	78	178	0.81
	2	81.0	11.9	66	152	0.80
	3	81.7	9.8	61	138	0.76
Average		80.2	11.1	68	156	0.82
Defruited	1	75.3	12.8	79	201	0.82
	2	73.5	14.2	93	238	0.90
	3	73.8	10.5	88	199	0.76
Average		74.2	12.5	87	213	0.83
Oh41						
Normal	1	86.6	7.2	53	115	0.85
	2	83.9	10.0	57	107	0.66
	3	85.4	10.1	76	129	0.87
Average		85.3	9.1	62	117	0.77
Defruited		None available				
B2						
Normal	1	79.9	13.4	101	181	0.90
	2	79.8	14.5	110	193	0.96
	3	77.2	16.2	119	216	0.95
Average		79.0	14.7	110	197	0.94
Defruited	1	78.1	17.1	127	204	0.95
	2	75.3	17.5	121	227	0.92
	3	77.3	18.6	131	208	0.92
Average		76.9	17.7	126	213	0.93

Table 13. Sample date averages for mg. reducing sugar, sucrose, and total sugar per cc. of tissue of the first internode above the uppermost brace roots of normal and defruited plants and for mg. total dissolved solids per cc. of first internode tissue based on calculations involving per cent total dissolved solids of second internode moisture percentage on a fresh weight basis and grams fresh weight per cc. of first internode tissue in 1954

Variety treatment and date	Number of plants	Reducing sugar mg./cc.	Sucrose mg./cc.	Total sugar mg./cc.	Total dissolved solids mg./cc.
Wf9					
Normal					
July 28	5	35	46	81	76
Aug. 4	9	34	66	100	96
Aug. 11	1	57	7	64	97
Aug. 18	6	24	73	97	98
Defruited					
July 26	4	39	37	76	80
Aug. 4	6	49	68	117	119
Aug. 11	2	37	74	111	130
Aug. 18	4	29	100	129	122
38-11					
Normal					
Aug. 4	11	27	7	34	52
Aug. 18	6	22	20	42	60
Sept. 21	7	25	37	62	67
Defruited					
Aug. 18	3	24	36	60	77
Sept. 21	5	28	55	83	85
Oh41					
Normal					
Aug. 4	11	30	39	69	74
Aug. 18	5	24	42	66	76
Sept. 21	7	21	27	48	60
Defruited					
Aug. 18	4	47	46	93	122
Sept. 21	1	28	53	81	100

Table 13. (Continued)

Variety treatment and date	Number of plants	Reducing sugar mg./cc.	Sucrose mg./cc.	Total sugar mg./cc.	Total dissolved solids mg./cc.
OS420					
Normal					
July 28	10	28	16	44	61
Aug. 4	13	30	40	70	80
Aug. 18	5	19	66	85	86
Defruited					
Aug. 18	3	28	63	91	89
B2					
Normal					
Aug. 4	13	34	23	57	75
Aug. 18	7	30	59	89	103
Sept. 21	8	49	41	90	110
Defruited					
Aug. 18	3	33	75	108	126
Sept. 21	3	56	50	106	130
B14					
Normal					
July 28	11	31	15	46	63
Aug. 4	11	34	16	50	66
Aug. 18	8	35	27	62	78
Defruited					
Aug. 18	3	29	59	88	99

Table 14. Date of silking in each replicate in 1955. Date of silking is that date on which 50 per cent of the ear bearing plants showed 1 inch of silks

Variety	Replicate		
	1	2	3
Wf9	July 24	July 31	July 31
38-11	August 6	August 7	August 6
Oh41	August 2	August 2	August 5
OS420	August 9	August 9	August 13
B2	August 9	August 13	August 8
B14	August 2	August 5	August 8

Table 15. Replicate and field averages of moisture content as per cent of fresh weight (moisture %), per cent total dissolved solids in expressed stalk sap (TDS %), mg.total dissolved solids per cc. of tissue (mg. TDS per cc.), mg. total dry matter per cc. of tissue (mg. TDM per cc.), and grams of fresh weight per cc. of tissue (density) pith cores and whole first internodes above the uppermost brace roots in 1955. The replicate averages of all indices are based on three stalk samples. The per cent total dissolved solids data of the first internode were used for both whole internode and pith core calculations of mg. total dissolved solids per cc. of tissue

Variety and replicate	Moisture %	TDS %	Mg. TDS per cc.	Mg. TDM per cc.	Density
	July 26, 1955, pith core tissue				
Wf9					
1	90.7	7.9	68	88	0.95
2	89.8	8.7	75	98	0.96
3	89.7	8.9	80	102	1.00
Average	90.1	8.5	74	96	0.97
38-11					
1	93.9	3.5	18	33	0.55
2	93.9	4.2	25	36	0.59
3	94.5	4.0	27	40	0.73
Average	94.1	3.9	23	36	0.62
Oh41					
1	92.4	5.3	37	52	0.77
2	92.9	6.0	37	46	0.67
3	89.6	7.6	34	50	0.50
Average	91.6	6.3	36	49	0.65
OS420					
1	93.3	4.1	24	42	0.63
2	89.7	6.2	23	41	0.40
3	92.1	4.9	25	44	0.56
Average	91.7	5.1	24	42	0.53
B2					
1	93.9	5.2	48	61	0.99
2	92.9	6.5	60	71	0.99
3	92.9	6.5	61	71	1.00
Average	93.2	6.1	56	68	0.99

Table 15. (Continued)

Variety and replicate	Moisture %	TDS %	Mg. TDS per cc.	Mg. TDM per cc.	Density
B14					
1	94.0	5.3	47	57	0.95
2	93.7	5.6	52	62	0.98
3	94.3	5.1	46	55	0.95
Average	94.0	5.3	48	58	0.96
	August 2, 1955, pith core tissue				
Wf9					
1	89.9	9.2	80	98	0.97
2	88.4	9.7	83	113	0.97
3	87.3	10.4	93	129	1.02
Average	88.5	9.8	85	113	0.99
38-11					
1	94.1	4.3	27	39	0.67
2	93.3	4.3	23	38	0.56
3	92.7	4.8	26	41	0.57
Average	93.4	4.5	25	39	0.60
Oh41					
1	91.8	6.9	52	67	0.79
2	90.2	7.1	41	62	0.67
3	90.4	7.4	35	48	0.51
Average	90.7	7.1	43	59	0.66
OS420					
1	91.2	5.7	28	47	0.56
2	85.3	8.6	23	47	0.32
3	89.0	5.7	21	43	0.40
Average	88.5	6.7	24	46	0.43
B2					
1	93.3	5.7	52	66	0.98
2	92.0	6.3	53	73	0.91
3	92.9	6.9	63	74	0.98
Average	92.7	6.3	56	71	0.96
B14					
1	93.1	6.1	55	67	0.97
2	91.4	6.8	54	75	0.88

Table 15. (Continued)

Variety and replicate	Moisture %	TDS %	Mg. TDS per cc.	Mg. TDM per cc.	Density
3	93.7	5.1	45	60	0.85
Average	92.7	6.0	51	67	0.93
	August 2, 1955, whole internode tissue				
Wf9					
1	82.5		72	168	0.96
2	81.7		73	169	0.92
3	79.5		79	208	0.97
Average	81.2		75	182	0.95
38-11					
1	83.9		31	90	0.87
2	89.1		29	82	0.75
3	89.3		37	91	0.85
Average	87.4		32	88	0.82
Oh41					
1	88.0		53	105	0.88
2	88.1		56	107	0.91
3	88.2		52	98	0.83
Average	88.1		54	103	0.87
OS420					
1	86.8		39	105	0.80
2	83.2		46	109	0.64
3	85.4		33	96	0.66
Average	85.1		39	103	0.70
B2					
1	89.4		48	99	0.93
2	88.5		52	108	0.93
3	88.0		56	114	0.92
Average	88.6		52	107	0.93
B14					
1	84.4		48	144	0.93
2	83.3		50	149	0.90
3	85.6		34	133	0.93
Average	84.4		44	142	0.92

Table 15. (Continued)

Variety and replicate	Moisture %	TDS %	Mg. TDS per cc.	Mg. TDM per cc.	Density
		August 9, 1955, pith core tissue			
Wf9					
1	86.4	13.2	107	132	0.97
2	85.7	12.4	95	129	0.90
3	84.9	12.6	95	135	0.89
Average	85.7	12.7	99	132	0.92
38-11					
1	93.2	5.1	28	40	0.60
2	93.0	5.9	34	44	0.63
3	89.4	6.0	21	40	0.41
Average	91.9	5.7	28	41	0.55
Oh41					
1	90.1	9.6	65	74	0.75
2	90.4	8.9	57	67	0.71
3	88.2	8.5	32	49	0.42
Average	89.6	9.0	51	63	0.63
OS420					
1	92.0	5.4	35	53	0.67
2	86.1	8.0	23	47	0.35
3	87.7	8.3	31	53	0.43
Average	88.6	7.2	30	51	0.48
B2					
1	92.2	7.2	66	77	1.00
2	93.4	5.9	49	59	0.88
3	92.8	6.4	59	71	0.99
Average	92.8	6.5	58	69	0.96
B14					
1	91.0	8.6	77	89	0.98
2	92.3	7.8	72	77	0.99
3	92.4	6.3	53	69	0.90
Average	91.9	7.6	67	78	0.96
		August 16, 1955, pith core tissue			

Table 15. (Continued)

Variety and replicate	Moisture %	TDS %	Mg. TDS per cc.	Mg. TDM per cc.	Density
Wf9					
1	80.4	17.8	154	211	1.08
2	81.9	15.9	131	183	1.01
3	83.9	14.0	113	156	0.97
Average	82.1	15.9	133	183	1.02
38-11					
1	89.6	7.2	33	51	0.52
2	89.4	9.0	43	56	0.54
3	90.0	8.0	40	56	0.56
Average	89.7	8.1	39	54	0.54
Oh41					
1	89.3	10.7	71	88	0.74
2	86.4	12.0	61	79	0.58
3	87.3	11.8	55	67	0.54
Average	87.7	11.5	62	78	0.62
OS420					
1	84.4	11.2	33	55	0.36
2	88.6	9.9	65	80	0.71
3	84.6	9.1	23	45	0.26
Average	85.9	10.1	40	60	0.44
B2					
1	90.2	8.8	82	101	1.03
2	91.9	6.7	56	74	0.91
3	91.9	7.4	64	77	0.94
Average	91.3	7.6	67	84	0.96
B14					
1	88.0	10.1	89	120	0.99
2	88.9	10.3	91	111	0.99
3	90.0	8.1	55	73	0.77
Average	89.0	9.5	78	101	0.92
	August 23, 1955, with core tissue				
Wf9					
1	91.9	17.5	164	198	1.02
2	79.7	18.7	150	205	1.00
3	84.5	12.5	74	105	0.71
Average	85.4	16.2	129	169	0.91

Table 15. (Continued)

Variety and replicate	Moisture %	TDS %	Mg. TDS per cc.	Mg. TDM per cc.	Density
38-11					
1	88.5	8.7	39	58	0.51
2	89.0	8.4	34	49	0.45
3	89.2	8.5	36	51	0.47
Average	88.9	8.5	36	53	0.48
Oh41					
1	86.9	12.7	79	94	0.72
2	85.5	12.8	54	70	0.50
3	83.3	12.9	30	47	0.28
Average	85.2	12.8	54	70	0.50
OS420					
1	85.7	12.2	55	76	0.53
2	83.2	13.3	47	69	0.43
3	83.7	10.8	33	54	0.34
Average	84.2	12.1	45	66	0.43
B2					
1	90.4	9.0	80	95	0.99
2	90.3	7.9	50	67	0.69
3	91.3	6.6	44	61	0.71
Average	90.7	7.8	58	74	0.79
B14					
1	86.2	13.3	118	147	1.06
2	86.9	12.9	113	134	1.01
3	88.6	11.8	107	117	1.02
Average	87.2	12.7	113	133	1.03
	August 23, 1955, whole internode tissue				
Wf9					
1	74.2		137	274	1.06
2	73.8		144	277	1.04
3	81.0		94	177	0.93
Average	76.3		125	243	1.01
38-11					
1	84.9		66	135	0.89

Table 15. (Continued)

Variety and replicate	Moisture %	TDS %	Mg. TDS per cc.	Mg. TDM per cc.	Density
2	85.2		62	129	0.87
3	85.8		60	117	0.82
Average	85.3		63	127	0.86
Oh41					
1	83.7		102	157	0.96
2	83.5		95	147	0.89
3	83.9		88	132	0.81
Average	83.7		95	145	0.89
OS420					
1	79.9		86	177	0.88
2	79.6		82	158	0.78
3	81.4		61	125	0.66
Average	80.3		76	153	0.77
B2					
1	85.3		78	150	1.02
2	87.1		62	117	0.91
3	88.5		53	103	0.90
Average	87.0		64	123	0.94
B14					
1	77.2		102	234	1.02
2	77.5		104	235	1.04
3	79.6		97	211	1.03
Average	78.1		101	227	1.03
	August 30, 1955, pith core tissue				
Wf9					
1	79.6	18.0	152	217	1.06
2	81.0	17.3	121	166	0.87
3	82.5	15.7	101	134	0.77
Average	81.0	17.0	125	172	0.90
38-11					
1	87.0	10.1	51	72	0.59
2	88.3	9.4	47	66	0.58
3	87.6	10.0	44	59	0.48
Average	87.6	9.8	47	66	0.55

Table 15. (Continued)

Variety and replicate	Moisture %	TDS %	Mg. TDS per cc.	Mg. TDM per cc.	Density
Oh41[a]					
1	85.5	13.4	87	110	0.77
2	83.0	15.5	84	110	0.65
3	84.6	15.2	95	114	0.87
Average	84.4	14.7	89	111	0.76
OS420					
1	81.0	13.3	40	71	0.37
2	86.4	9.7	40	63	0.40
3	73.9	15.7	21	48	0.18
Average	80.4	12.9	34	61	0.32
B2					
1	87.9	7.3	61	83	0.91
2	90.4	7.9	61	81	0.95
3	90.5	7.7	60	81	0.86
Average	89.6	7.6	61	82	0.91
B14					
1	82.5	15.6	119	162	0.92
2	83.9	15.3	129	162	1.00
3	89.1	9.3	66	87	0.73
Average	85.2	13.4	105	137	0.88
	September 14, 1955, pith core tissue				
Wf9					
1	81.6	15.5	90	129	0.70
2	80.4	15.8	88	135	0.69
3	82.6	13.8	82	123	0.71
Average	81.5	15.0	87	129	0.70
38-11					
1	83.2	10.3	46	61	0.53
2	86.1	13.2	59	72	0.52
3	82.4	13.1	40	64	0.37
Average	83.9	12.2	48	66	0.47

[a]Majority of plants sampled were internally discolored and were therefore not considered as representative of normal plants. No interpretation should be made from the data obtained for Oh41 at this date.

Table 15. (Continued)

Variety and replicate	Moisture %	TDS %	Mg. TDS per cc.	Mg. TDM per cc.	Density
Oh41					
1	84.0	14.3	60	79	0.51
2	78.3	16.9	44	71	0.33
3	77.1	15.2	24	47	0.21
Average	79.8	15.5	43	66	0.35
OS420					
1	79.1	10.7	21	42	0.24
2	78.3	11.3	20	47	0.22
3	65.6	17.2	12	36	0.10
Average	74.3	13.1	18	42	0.19
B2					
1	90.7	8.2	64	80	0.86
2	88.5	6.7	21	41	0.36
3	91.5	6.7	43	60	0.71
Average	90.2	7.2	43	60	0.64
B14					
1	82.4	15.9	126	169	0.96
2	81.2	17.4	115	153	0.82
3	86.4	10.4	46	70	0.50
Average	83.3	14.6	96	131	0.76
	September 14, 1955, whole internode tissue				
Wf9					
1	75.6		111	230	0.94
2	74.6		109	236	0.93
3	76.7		99	218	0.93
Average	75.6		106	228	0.93
38-11					
1	83.2		77	150	0.89
2	81.6		95	164	0.88
3	79.7		84	162	0.80
Average	81.5		85	159	0.86
Oh41					
1	81.3		104	167	0.89
2	78.1		106	179	0.80
3	79.9		88	147	0.73
Average	79.8		99	164	0.81

Table 15. (Continued)

Variety and replicate	Moisture %	TDS %	Mg. TDS per cc.	Mg. TDM per cc.	Density
OS420					
1	76.3		47	135	0.57
2	76.2		43	117	0.49
3	64.5		32	100	0.28
Average	72.3		41	117	0.45
B2					
1	85.3		67	141	0.96
2	85.6		38	96	0.67
3	87.8		53	109	0.90
Average	86.2		53	115	0.84
B14					
1	74.6		125	267	1.05
2	74.0		131	266	1.02
3	80.0		74	179	0.89
Average	76.2		110	237	0.99
	October 4, 1955, pith core tissue				
Wf9					
1	86.1	11.8	69	95	0.69
2	78.1	12.0	31	66	0.34
3	83.4	8.5	23	55	0.33
Average	82.5	10.8	41	72	0.45
38-11					
1	88.0	9.2	29	44	0.36
2	86.5	10.2	31	44	0.34
3	82.3	10.1	20	39	0.23
Average	85.6	9.8	27	42	0.31
B2					
1	90.0	7.2	37	57	0.57
2	83.0	----	--	47	0.28
3	85.9	8.7	30	59	0.44
Average	86.3	8.0	34	54	0.43
B14					
1	85.6	12.6	91	116	0.83
2	84.8	11.4	60	91	0.61
3	80.2	4.4	5	29	0.15
Average	83.5	9.5	52	79	0.53

Table 16. Date of silking in each replicate in 1956. Date of silking is that date on which 50 per cent of the ear bearing plants showed 1 inch of silks. All varieties silked in July

Variety	Replicate			
	1	2	3	4
Ia153	14	14	14	15
Oh29	30	31	31	31
M14	21	24	24	30
R101	24	27	27	28
W22R	20	21	23	24
B2	27	28	31	30
B14	27	24	28	29
W17RB	24	27	27	29
Wf9 x 38-11	16	23	28	22
Wf9 x M14	16	16	16	23
C131 x B14	16	18	23	24
Wf9 x B14	16	18	23	16
Oh41	27	27	28	27
187-2	27	28	27	30
B14 x OS420	16	16	20	16
38-11	29	29	31	30
Wf9	21	23	27	28
B37	26	27	29	30
OS420	21	20	24	27
B14 x Oh41	16	16	23	24

Table 17. Replicate and field average of grams of fresh weight per cc. of pith core tissue of first and fourth internodes above the uppermost brace roots in 1956. The replicate averages are based on three stalk samples. The least significant difference (LSD) for each sample date is given in the table. The least significant difference for the first internode pith core density over all sample dates was 0.16 at the 5 per cent level and 0.21 at the 1 per cent level

Variety	Replicate 1	2	3	4	Field average
		July 18, 1956, first internode			
Ia153	0.63	0.67	0.59	0.58	0.62
Oh29	0.63	0.70	0.81	0.71	0.71
M14	0.85	0.92	0.89	0.91	0.89
R101	0.90	0.95	0.97	0.98	0.95
W22R	0.87	0.75	0.90	0.88	0.85
B2	0.99	0.99	1.00	1.00	1.00
B14	0.97	0.91	0.98	0.94	0.95
W17RB	0.97	0.91	0.91	0.99	0.95
Wf9 x 38-11	0.66	0.83	0.95	0.70	0.79
Wf9 x M14	0.82	0.77	0.77	0.89	0.81
C131 x B14	0.66	0.77	0.92	0.92	0.82
Wf9 x B14	0.92	0.88	0.96	0.88	0.91
Oh41	0.46	0.63	0.60	0.55	0.56
187-2	0.60	0.82	0.82	0.74	0.75
B14 x OS420	0.80	0.89	0.93	0.86	0.87
38-11	0.77	0.73	0.82	0.84	0.79
Wf9	0.93	0.90	0.92	0.98	0.93
B37	0.93	0.94	0.85	0.76	0.87
OS420	0.45	0.55	0.67	0.67	0.59
B14 x Oh41	0.86	0.86	0.85	0.85	0.86
LSD = 0.09 at 5 per cent level, 0.12 at 1 per cent level					
		August 4, 1956, first internode			
Ia153	0.57	0.49	0.65	0.46	0.54
Oh29	0.75	0.63	0.72	0.60	0.68
M14	0.97	0.93	0.90	0.85	0.91
R101	0.99	1.00	1.00	0.98	0.99
W22R	0.80	0.97	0.92	0.86	0.89
B2	1.01	1.01	1.01	1.00	1.00
B14	1.02	1.00	0.97	1.00	1.00
W17RB	0.89	0.96	0.96	0.90	0.93

Table 17. (Continued)

Variety	Replicate 1	2	3	4	Field average
Wf9 x 38-11	0.85	0.74	0.85	0.92	0.84
Wf9 x M14	0.92	0.91	0.97	0.94	0.94
C131 x B14	0.80	0.80	0.92	0.93	0.86
Wf9 x B14	0.94	0.97	0.96	0.99	0.97
Oh41	0.61	0.56	0.48	0.56	0.55
187-2	0.65	0.95	0.88	0.82	0.83
B14 x OS420	0.84	0.86	0.88	0.95	0.88
38-11	0.66	0.76	0.79	0.87	0.77
Wf9	0.98	0.99	1.00	0.94	0.98
B37	0.95	0.96	0.93	0.71	0.89
OS420	0.59	0.74	0.70	0.76	0.70
B14 x Oh41	0.87	0.82	0.76	0.92	0.84
LSD = 0.08 at the 5 per cent level, 0.11 at the 1 per cent level					
	August 4, 1956, fourth internode				
Ia153	----	----	----	----	----
M14	0.58	0.48	0.59	0.46	0.53
R101	0.60	0.53	0.51	0.61	0.56
W22R	0.45	0.44	0.50	0.43	0.46
B2	0.96	1.01	1.00	1.00	0.99
B14	0.48	0.57	0.74	0.68	0.62
W17RB	0.48	0.45	0.67	0.87	0.62
Wf9 x 38-11	0.29	0.29	0.51	0.43	0.38
Wf9 x M14	0.34	0.36	0.40	0.56	0.42
C131 x B14	0.26	0.29	0.47	0.45	0.38
Wf9 x B14	0.41	0.43	0.58	0.57	0.50
Oh41	0.26	0.25	0.25	0.37	0.28
187-2	0.36	0.46	0.50	0.49	0.45
B14 x OS420	0.33	0.39	0.58	0.49	0.45
38-11	0.34	0.39	0.45	0.46	0.41
Wf9	0.27	0.39	0.40	0.64	0.43
B37	0.48	0.46	0.48	0.41	0.46
OS420	0.28	0.40	0.35	0.44	0.37
B14 x Oh41	0.31	0.30	0.31	0.37	0.32
	August 15, 1956, first internode				
Ia153	0.44	0.37	0.50	0.59	0.48
Oh29	0.68	0.57	0.79	0.69	0.68
M14	0.94	0.89	0.98	1.02	0.96
R101	0.98	1.00	1.00	0.98	0.99

Table 17. (Continued)

Variety	Replicate 1	2	3	4	Field average
W22R	0.85	0.90	0.88	0.84	0.87
B2	0.88	1.02	1.02	1.01	0.98
B14	1.01	0.99	0.99	1.01	1.00
W17RB	0.94	0.98	0.90	0.95	0.94
Wf9 x 38-11	0.72	0.88	0.93	0.66	0.80
Wf9 x M14	0.60	0.87	0.86	0.90	0.81
C131 x B14	0.75	0.79	0.86	0.87	0.82
Wf9 x B14	0.96	0.92	0.98	0.94	0.95
Oh41	0.56	0.53	0.40	0.49	0.50
187-2	0.73	0.81	0.77	0.75	0.77
B14 x OS420	0.93	0.91	0.91	0.97	0.93
38-11	0.68	0.69	0.75	0.77	0.72
Wf9	1.00	1.01	0.91	0.89	0.95
B37	1.00	0.84	0.91	0.78	0.88
OS420	0.56	0.71	0.71	0.67	0.66
B14 x Oh41	0.74	0.81	0.72	0.89	0.79
LSD = 0.10 at the 5 per cent level, 0.13 at the 1 per cent level					
August 31, 1956, first internode					
Ia153	0.24	0.27	0.26	0.43	0.30
Oh29	0.92	0.61	0.61	0.79	0.73
M14	0.86	0.90	0.97	0.95	0.92
R101	0.95	0.99	0.99	0.99	0.98
W22R	0.60	0.80	0.67	0.78	0.71
B2	1.03	1.01	1.02	1.02	1.02
B14	1.00	1.02	0.98	1.02	1.01
W17RB	0.70	0.89	0.71	0.62	0.73
Wf9 x 38-11	0.57	0.72	0.93	0.73	0.74
Wf9 x M14	0.78	0.81	0.60	0.94	0.78
C131 x B14	0.76	0.76	0.82	0.87	0.80
Wf9 x B14	0.77	0.90	0.91	0.92	0.88
Oh41	0.50	0.55	0.50	0.40	0.49
187-2	0.57	0.84	0.74	0.74	0.72
B14 x OS420	0.70	0.77	0.95	0.94	0.84
38-11	0.70	0.70	0.83	0.77	0.75
Wf9	0.79	0.99	0.99	0.99	0.94
B37	0.90	0.91	0.90	0.82	0.88
OS420	0.36	0.43	0.55	0.63	0.49
B14 x Oh41	0.73	0.82	0.76	0.84	0.79
LSD = 0.12 at the 5 per cent level, 0.16 at the 1 per cent level					

Table 17. (Continued)

Variety	Replicate 1	2	3	4	Field average
	September 7, 1956, first internode				
Ia153	0.17	0.12	0.24	0.17	0.18
Oh29	0.57	0.69	0.62	0.68	0.64
M14	0.91	0.90	0.93	0.90	0.91
R101	0.95	0.98	1.01	0.98	0.98
W22R	0.66	0.73	0.85	0.73	0.74
B2	1.02	1.01	1.02	1.00	1.01
B14	0.98	1.02	1.02	1.01	1.01
W17RB	0.80	0.93	0.84	0.86	0.86
Wf9 x 38-11	0.57	0.81	0.94	0.77	0.77
Wf9 x M14	0.78	0.76	0.71	0.94	0.80
C131 x B14	0.85	0.83	0.87	0.98	0.88
Wf9 x B14	0.93	0.92	0.91	0.93	0.92
Oh41	0.81	0.66	0.46	0.48	0.60
187-2	0.69	0.87	0.74	0.79	0.77
B14 x OS420	0.67	0.93	0.96	0.96	0.88
38-11	0.71	0.71	0.85	0.86	0.78
Wf9	0.93	0.84	0.91	0.87	0.88
B37	0.95	0.99	0.90	0.90	0.94
OS420	0.48	0.65	0.39	0.78	0.58
B14 x Oh41	0.65	0.66	0.75	0.91	0.74
LSD = 0.12 at the 5 per cent leve, 0.16 at the 1 per cent level					
	September 7, 1956, fourth internode				
Ia153	----	----	----	----	----
Oh29	0.36	0.38	0.52	0.37	0.41
M14	0.48	0.45	0.56	0.42	0.48
R101	0.68	0.58	0.55	0.61	0.61
W22R	0.39	0.36	0.35	0.41	0.38
B2	0.98	0.99	1.01	0.98	0.99
B14	0.47	0.53	0.76	0.72	0.62
W17RB	0.38	0.41	0.57	0.56	0.48
Wf9 x 38-11	0.27	0.31	0.58	0.46	0.41
Wf9 x M14	0.27	0.30	0.30	0.68	0.39
C131 x B14	0.34	0.26	0.33	0.45	0.35
Wf9 x B14	0.45	0.41	0.45	0.59	0.48
Oh41	0.35	0.29	0.32	0.30	0.32
187-2	0.34	0.47	0.40	0.45	0.42
B14 x OS420	0.29	0.50	0.65	0.44	0.47
38-11	0.33	0.32	0.39	0.47	0.38
Wf9	0.42	0.34	0.47	0.64	0.47

Table 17. (Continued)

Variety	Replicate 1	2	3	4	Field average
B37	0.55	0.58	0.40	0.44	0.49
OS420	0.24	0.34	0.20	0.58	0.34
B14 x Oh41	0.24	0.37	0.27	0.36	0.31